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Finschia—A Genus of "Nut" Trees of the Southwest Pacific

C. T. WHITE[1]

INTRODUCTION

A PLANT FAMILY with a most interesting and intriguing distribution is Proteaceae, which finds its greatest development in Australia (650 species) on the one hand and South Africa (300 species) on the other, though the two countries have no genera in common. Practically all the South African species and the vast majority of Australian ones are markedly xerophytic. The largest genus, *Grevillea* R. Br., consists mainly of xerophytic shrubs or small trees but a few are large trees found in the rain forests of tropical and subtropical eastern Australia, New Guinea, and New Caledonia. In the southwest Pacific area the family finds its greatest development in northeastern Australia, where trees belonging to it provide the great bulk of cabinet timbers known in the trade as "Silky Oaks." There is close affinity between the Proteaceae of eastern Australia and of western South America as illustrated by the genera *Embothrium* Forst. which has four species in South America, two in Australia, and one in New Guinea, and *Lomatia* R. Br. which has four species in South America and eight in Australia. The endemic Australian genus *Telopea* R. Br. is separated from *Embothrium* Forst. on very slender grounds, and Diels (1916: 200), with some doubt, records the genus *Euplassa* Salisb., otherwise consisting of eight South American species, as Papuan and Australian (one species each).

An outstanding feature of the flora of the rain-forest belt of northeastern Australia is the number of monotypic or very small genera of Proteaceae developed in it, e. g., *Austromuellera* C. T. White, *Buckinghamia* F. Muell., *Cardwellia* F. Muell., *Carnarvonia* F. Muell., *Darlingia* F. Muell., *Hollandaea* F. Muell. (two spp.), *Musgravea* F. Muell., and *Placospermum* White & Francis. A surprising feature is the absence, with the exception of one species in New Zealand, of the family from Polynesia.

There is in the islands of the southwest Pacific—Caroline Islands, New Guinea, Solomon Islands, and the New Hebrides—a group of trees with the floral characters of *Grevillea* R. Br. and the fruit of *Helicia* Lour. These, I consider, all belong to *Finschia* Warb. This genus was founded by Warburg (1891: 297) on a tree from northeastern New Guinea. His original description would cover *Grevillea* R. Br. exactly though he does not mention this genus and on the following page the distinctions he gives for separating his proposed new genus from *Helicia* are exactly those which distinguish *Grevillea* from that genus. H. Sleumer (1939: 127), in a more recent contribution to our knowledge of Papuan Proteaceae, includes *Finschia* Warb. in *Grevillea* R. Br. and gives a key to the New Guinean species. Lauterbach (1913: 329), in a key to the Papuan genera of Proteaceae, distinguishes *Finschia* Warb. from *Grevillea* R. Br. by the fruit being scarcely dehiscent. Later Diels (1916: 205), in an account of new Papuan Proteaceae, referred to this and stated that Lauterbach's conclusions were unfounded as fruits of neither *F. rufa* Warb. nor *F. chloroxantha* Diels, the only two species so far described, were known. An emended description of the genus and a key to the species are offered here, a new species is described, and a new combination proposed.

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Finschia Warburg
(Emended description)

Flowers hermaphroditic. Petals (perianth segments) curved and united in the bud stage, soon free. Anthers sessile or nearly so within the concave laminae or tips of the petals, connective broad, not produced beyond the anther cells, anther cells slightly divergent towards the base. Torus oblique. Hypogynous gland fleshy, entire, horseshoe-shaped or nearly annular; ovary stipitate, style slender or narrowly clavate, usually long and protruding from the split on the lower side of the perianth tube in the later bud stage. Fruit an indehiscent drupe; exocarp thin, fleshy; endocarp bony, rough; cotyledons 2, thick and fleshy and filling the seed. Trees, trunk buttressed, often raised on stilt roots. Leaves entire. Inflorescence racemose, racemes axillary or on the older wood below the leaves.

Type species: *F. rufa* Warb. (1891: 297).

Four species in the rain forests of Micronesia (Caroline Islands), New Guinea, Solomon Islands, and the New Hebrides.

Key to the Species

Leaves densely rufous- or ferruginous-pubescent beneath.
- Leaves 28–35 cm. long, 11–13 (to 17) cm. wide; inflorescence to 40 cm. long . . . . . 1. *F. rufa*
- Leaves 18–25 (to 28) cm. long, 6–9 cm. broad; inflorescence 24–26 cm. long . . . . . 2. *F. Carrii*

Leaves glabrous.
- Flowers very densely ferruginous-pubescent; fruit globose, not laterally compressed, over 4 cm. diam. . . . . 3. *F. ferruginiflora*
- Flowers thinly ferruginous-pubescent in the bud stage, almost glabrous when fully developed; fruit laterally compressed, not above 4 cm. diam. . . . . 4. *F. chloroxantha*

In the following account of the species the letters B.S.I.P. and N.G.F., preceding the collectors' numbers, stand for British Solomon Islands Protectorate and New Guinea Forests, respectively. The first precedes all specimens collected in the Solomon Islands by F. S. Walker and myself in 1945–1946 and the latter those made in New Guinea under the direction of Major J. B. McAdam, C.R.E., New Guinea Forests, by officers and men of his unit headquarters and two associated forest survey companies.

1. **Finschia rufa** Warburg (1891: 298)
Grevillea rufa (Warburg) Sleumer (1939: 128).

Tree. Leaves large, coriaceous, shortly petiolate, apex obtuse or rotundate, base acuminate, entire, adult leaves glabrous above, the midrib and main nerves rather prominent, rufous- or ferruginous-tomentose beneath, the midrib, lateral nerves, and the veins very prominent, lateral nerves about 20 on each side of the midrib, not markedly curved, joined below the margin and united with an intramarginal vein close to the edge; blade 25–35 cm. long, 11–13 (to 17) cm. wide; petiole 2 cm. long. Racemes 17–40 cm. long; rachis, pedicels, and flowers densely clothed with red-brown hairs (rufous-villous). Flowers solitary or in pairs, pedicels 1 mm. long; petals (perianth segments) about 1 cm. long, glabrous on the inner face; ovary stipitate, seated obliquely on a 3-mm. long stipes, style 7 mm. long; torus oblique, hypogynous gland annular or nearly so. Fruit unknown.

Northeast New Guinea: Only known from the neighbourhood of Sattelberg where, according to Sleumer, *loc. cit.*, it has been collected several times. *(Warburg 20496,* type: *Hellwig 531, Clemens 2234* and *8094 A.)*

Unfortunately I have not seen specimens and the above description is drawn from that of the author's original and from the few notes in Sleumer's key. According to Warburg, the pedicels are only 1 mm. long, which would give the inflorescence almost a spicate appearance which, apart from the larger leaves, should distinguish it from the next species.

2. **Finschia Carrii** (Sleumer) C. T. White *comb. nov.*
Grevillea Carrii Sleumer (1939: 128).

Tree, about 12 m. high, branchlets densely

FIG. 1. *Finschia ferruginiflora* C. T. White. New Guinea: *L. S. Smith 1093* (flowers) and *1060* (fruits). A, flower (slightly enlarged); B, gynaeceum (slightly enlarged); C. fruit.

rufous- or ferruginous-pubescent. Leaves narrowly obovate, apex rounded, base cuneate, chartaceous, glabrous above except for the midrib; lateral nerves from 14 in the smaller leaves to 24 in the larger ones on each side of the midrib, united to form a strong intramarginal vein 4–5 mm. from the edge with a finer less distinct one very close to the margin, slightly raised, connecting veins and veinlets clearly discernible in the dried specimens, densely rufous- or ferruginous-pubescent beneath, lateral nerves and connecting and reticulate veinlets raised and prominent; blade 13–28 cm. long, 6–9 cm. wide, petiole densely tomentose, 1.5–3 cm. long. Racemes mostly on the older wood below the leaves, very densely flowered, 24–30 cm. long including the short peduncle; rachis, pedicels, and flowers densely rufous- or ferruginous-tomentose; pedicels in pairs, slender, 4–5 mm. long. Petals (perianth segments) 7–8 mm. long, glabrous on the inner face, ovary densely clothed with rather long reddish hairs, stipitate; stipes glabrous, style glabrous, grooved, gradually thickened towards the top; stigma pyramidal; hypogynous gland very prominent, entire, horseshoe-shaped or almost annular.

Southeast New Guinea: Koitaki, alt. *ca.* 1,500 ft. in rain forest, *C. E. Carr No. 12058* (fls.), April, 1935 (tree 12 m.; fls. golden-yellow, tipped brownish-orange, style bright yellow-green, stigma deep green).

Though fruits are unknown, I have transferred this to *Finschia* Warb. owing to its close relationship to *F. rufa* Warb., from which it differs chiefly in being smaller in all its parts. The description has been drawn mainly from isotype material but a few notes from Sleumer's original description have been incorporated mainly to give variation in size of leaf and a few other characters. The species is known only from the type gathering.

3. **Finschia ferruginiflora** *sp. nov.*

Fig. 1

Arbor 30 m. alt., trunco per radices adventitios ad 1.5 m. altos supra terram elevato, cortice bruneo lenticellarum rimis notato, ramulis validis, partibus novellis ferrugineis mox glabris. Folia utrinque glabra, anguste obovata, apice rotundata, basi cuneata in petiolum validum angustata, chartacea, nervis lateralibus primariis utrinsecus 18–20, utrinque prominentibus, in venam intramarginalem 4–5 mm. a margine arcuatim confluentibus, venulis in sicco laxe reticulatis supra parum subtus distinctius elevatis; lamina 14–22 cm. longa, 3.5–5 cm. lata; petiolus 1–1.5 cm. longus. Racemi densiflori, axillares, saepe ex axillis foliorum delapsorum orti, breviter pedunculati, cum pedunculo 13–18 cm. longi, cum floribus pilis ferrugineis densissime obsiti; pedicelli graciles, ca. 1 cm. longi; torus obliquus, glandula hypogyna integra hippocrepiformi; petala (perianthii segmenta) 7–8 mm. longa; pistillum 1.2 cm. longum, ovario unilaterali fusco-piloso stipitato, stipite cum stylo glabrescenti. Fructus indehiscens, globosus, ca. 5 cm. diam., fere vel omnino sessilis, pericarpio tenui, endocarpio osseo 7–8 mm. crasso, sutura visibili sed indistincta.

Northeast New Guinea: Kuminkira, Aiyura, alt. about 5,000 ft., *L. S. Smith N.G.F. 1093* (Type: flowers) October, 1944 (tree 100 ft., with adventitious roots up to 4.5 feet above the ground; bark brownish, slightly dotted with pustular lenticels, very finely longitudinally cracked with a few small corky scaled patches; flowers rusty brown, style green with green stigma). Bracken Ridge, Aiyura, alt. about 6,000 ft., *L. S. Smith N.G.F. 1060* (fruits) October, 1944 (tree 100 ft., trunk raised on adventitious roots up to 3 feet above the ground; bark brownish with small pustular lenticels sometimes arranged in short longitudinal rows; fruits globular, brownish; seeds cooked and eaten by the natives).

4. **Finschia chloroxantha** Diels (1916: 204)

Figs. 2, 3

Grevillea densiflora C. T. White (1922: 25); H. Sleumer (1939: 129).

Grevillea elaeocarpifolia Guillaum. (1932: 87).

FIG. 2. *Finschia chloroxantha* Diels. Bougainville: *S. F. Kajewski 2033.*

Helicia micronesica Kanehira (1933a: 95, fig. 23 [fol. fruct.]; 1933b: 669; 1935: 311).
Finschia micronesica (Kanehira) Kanehira (1938: 241, fig. 72 [fl.]).
Finschia Waterhouseana B. L. Burtt (1936: 465).
Grevillea micronesi(a)ca (Kanehira) Sleumer (1939: 129).
Finschia densiflora (C. T. White) C. T. White (ex Walker, 1948: 155).

Tree up to 25 m. high, trunk buttressed, often raised on stilt roots; bark grey to light brown, usually marked with pustules in longitudinal lines; young parts densely clothed with a tawny or ferruginous pubescence. Leaves lanceolate, elliptic or narrowly obovate ("oblanceolate"), apex acute or blunt, base cuneate, in the dried state dull or nitid above; main lateral nerves from about 12 on each side of the midrib in the smaller leaves to about 30 in the larger ones, arching to form an intramarginal vein, sometimes very distinct, at others not very clearly defined; blade variable in size, 9–40 cm. long, 3.5–13 cm. wide; petiole 1–2.5 cm. long. Racemes many flowered, axillary or more frequently on the older wood below the leaves, rachis pubescent, to 30 cm. long, including the comparatively short peduncle. Flowers yellow-green to orange-yellow, pedicels and petals (perianth segments) thinly clothed with a few scattered brown hairs; pedicels 0.3–1 cm. long; petals 0.4–0.8 cm. long. Ovary glabrous, stipitate, stipes to 0.5 cm. long; style narrowly clavate, to 1.5 cm. long; torus very oblique, hypogynous gland prominent, entire, horseshoe-shaped or nearly annular. Fruit yellow, compressed, oblique, 3–4 cm. long, 2.5–3 cm. wide, and 2.5 cm. deep; endocarp bony, roughened; seed edible.

A very widely spread species from the Caroline Islands in the north through New Guinea and the Solomon Islands to the New Hebrides in the south. To the specimens cited by the authors quoted above the following can be added:

Northeast New Guinea: Heath Island, Open Bay (nr. New Britain), in rain forest on volcanic soil, *K. Mair, N.G.F. 1878* (flowers) May, 1945 (tree 60 ft., stilt-rooted to 2 ft. 6 in.; bark light brown with pustules in longitudinal lines; flowers yellow-green). Solomon Islands: New Georgia Group, Kolombangara Island, in lowland rain forest, *F. S. Walker & C. T. White B.S.I.P. 183* (leaves and seeds from under the tree) October, 1945 (tree 70 ft., buttresses supporting the trunk off the ground on stilt roots 6 ft. high; bark grey-brown, roughened with numerous fine pustular lenticels; seeds with an edible, pleasantly flavoured kernel).

It is with some hesitation that I have united all the species quoted above with *F. chloroxantha* Diels, especially as Sleumer *(loc. cit.)*, who had the opportunity of seeing the type of this species, kept it distinct from the others. Knowing, however, the extreme variability of many of the Proteaceae, especially when they are brought into cultivation, I have after considerable thought decided to regard *F. chloroxantha* Diels as a "formenkreis" species with several geographical races. It seems to differ from subsequently named species only in the larger leaves and longer inflorescences.

Sleumer *(loc. cit.)* suggested that *Grevillea elaeocarpifolia* Guillaum. was identical with *Grevillea densiflora* C. T. White but did not actually synonymise the two species. Kajewski when in Bougainville, according to his field labels, recognized the tree there as practically identical with the one in the New Hebrides. In this latter area he mentions that the trees are frequently seen about villages and appear to be planted as the seed is quite an important food nut. The New Hebrides tree which was aptly named by Guillaumin (1932) as *Grevillea elaeocarpifolia,* judging from Kajewski's material (two numbers), seems to have consistently smaller leaves, but this is an extraordinarily variable feature in the New Guinea tree of which I have seen a good range of specimens.

Finschia micronesica Kanehira, according to the author's description and illustrations, seems to differ in the inflorescence being much shorter

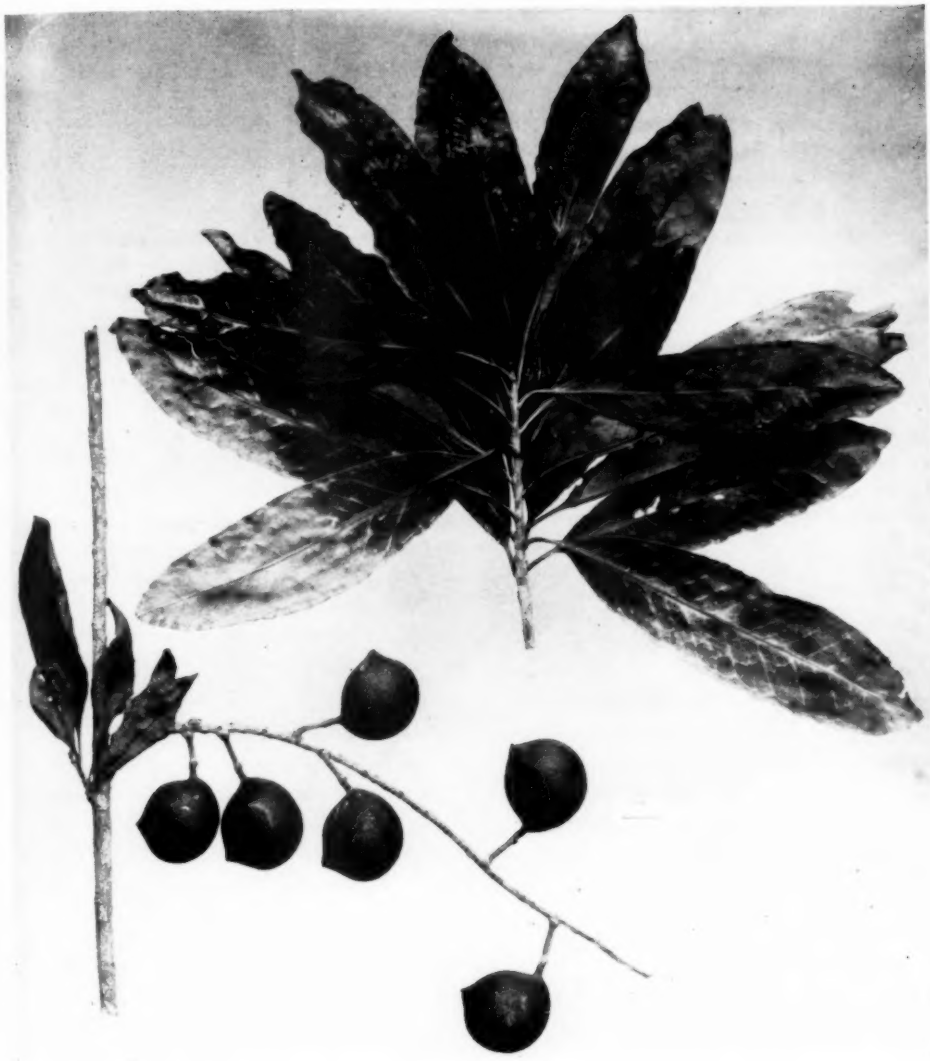

FIG. 3. *Finschia chloroxantha* Diels (*Grevillea elaeocarpifolia* Guillaumin). New Hebrides: *S. F. Kajewski 350.*

with fewer, less crowded flowers and in the fruits being slightly larger than in the New Guinea, Solomon Islands, and New Hebrides trees, but it is doubtful if these are points of specific value.

ACKNOWLEDGMENTS

I am indebted to the authorities of the Arnold Arboretum (Harvard University) for photostat copies of Kanehira's papers, which were unavailable to me in Brisbane, and to Mr. E. H. Flint of the Queensland University for a translation of Kanehira's original description (in Japanese) in *Flora Micronesica.*

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The Alcyonaria of Bikini and Other Atolls in the Marshall Group. Part I: The Gorgonacea[1]

FREDERICK M. BAYER[2]

THIS REPORT COVERS the alcyonarian corals collected during two expeditions to the Marshall Islands conducted by the United States Navy and other agencies. The Gorgonacea are considered in the present part, and the lesser groups (Stolonifera and Alcyonacea) will be taken up in Part II.

I wish to acknowledge my indebtedness to the Project Officer of the Bikini Scientific Resurvey Expedition (1947), Captain Christian L. Engleman, U. S. N.; to Dr. John W. Wells, United States Geological Survey, with whom I worked often in the field; to Dr. L. P. Schultz and Dr. J. P. E. Morrison, my colleagues of the U. S. National Museum, who extended every assistance possible; and last, but certainly not least, to Fred C. Zimmerman, Seaman 2/c, of the *Chilton's* crew, whose services were assigned me during a part of the expedition.

THE ALCYONARIA

The Alcyonaria inhabiting the coral reefs of the Pacific Ocean are a much less conspicuous element of the fauna than those of the tropical Atlantic. The reef-dwelling forms of the Pacific are the inconspicuous Alcyonacea and the stoloniferan, *Tubipora musica.* The only alcyonarian of real importance to reef formation is the blue coral, *Heliopora.* The holaxonian Gorgonacea occur only in the deeper waters of the lagoons and surrounding ocean and must be taken by dredge.

During "Operation Crossroads," the first expedition to the Marshalls, collecting was concentrated upon the reefs, and therefore few Alcyonaria, none of which were Gorgonacea, were obtained. However, on the second trip the LCI 615 was fitted for deep-water dredging, and under the direction of Dr. R. Dana Russell many hauls, which accounted for all but one of the gorgonacean species collected during the entire operation, were made in the waters surrounding Bikini Atoll. The alcyonaceans taken in the dredge, along with the littoral forms collected on the reefs of Bikini and Rongerik by the author and Fred Zimmerman, will be discussed in Part II of this report.

The classification of the Alcyonaria is not, in certain respects, entirely satisfactory. A case in point is the questionable scope of the family Muriceidae, whose species constitute the major portion of this paper. However, since the present report is in no sense revisionary, this aspect of the problem must await treatment in more comprehensive studies.

Since the literature concerning these animals has in the past been typified by inadequate and imperfect illustration of the species, it has been of primary concern to figure adequately, both microscopically and macroscopically, all the species herein discussed.

Gorgonacea were taken at four stations:

STATION 9. Off Bikini Atoll, 11° 29′ 16″ N., 165° 20′ 45″ E.; depth 50–96 fathoms. August 6, 1947.

STATION 12. Off the seaward shore of Bikini Island, Bikini Atoll, 11° 28′ 23″(?) N., 165° 31′ 35″(?) E.; depth 58–90 fathoms. August 7, 1947.

STATION 23. Bikini Lagoon, east end, Bikini Atoll, 11° 31′ 51″ N., 165° 32′ 53″ E.; depth 5–12 fathoms. August 15, 1947.

STATION 30. Off Enyu Pass, Bikini Atoll, 11° 29′ 28″ N., 165° 31′ 40″ E.; depth 116–120 fathoms. August 22, 1947.

[1] Published with the permission of the Secretary of the Smithsonian Institution. Manuscript received November 17, 1948.

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A list of the species collected by the Bikini Scientific Resurvey is given here:

Order GORGONACEA
Sub-order SCLERAXONIA

SUBEROGORGIIDAE

1. **Suberogorgia mollis** (Nutting)

Sub-order HOLAXONIA
KEROEIDIDAE

2. **Keroeides koreni** Wright and Studer

MURICEIDAE

3. **Paracis squamata** (Nutting)
4. **Paracis orientalis** (Ridley)
5. **Muricella englemani** new species
6. **Echinogorgia russelli** new species
7. **Villogorgia zimmermani** new species
8. **Villogorgia zimmermani** form **pallida** new
9. **Villogorgia compressa** Hiles

PRIMNOIDAE

10. **Caligorgia pseudoflabellum** new species

GORGONELLIDAE

11. **Scirpearia erythraea** Kükenthal
12. **Toeplitzella laevis** (Verrill)

Genus SUBEROGORGIA Gray
Suberogorgia mollis (Nutting)
Figs. 1*f*, 2 *g-h*; Pl. 4, fig. 1

Euplexaura mollis Nutting 1910*b*: 13, pl. 3, figs. 4, 4a; pl. 4, fig. 8.
Euplexaura mollis Kükenthal 1919: 224.
Euplexaura mollis Kükenthal 1924: 94.
Suberogorgia mollis Stiasny 1937: 98, text fig. FF; pl. 8, fig. 47.
Suberogorgia mollis Stiasny 1940*a*: 203.

Diagnosis: Colony erect, flabellate, branched in one plane; branching with frequent anastomosis forming a network with elongate rectangular meshes. Largest branches and the end twigs round in cross section, the intermediate ones flattened at right angles to the plane of branching. Twigs 1.5 to 2.0 mm. in diameter, flat branches about 7.0 by 10.0 mm. in diameter, large main branches 30 mm. and probably more. Anthocodiae retractile into very low verrucae scarcely separable from surrounding coenenchyma; aperture with eight distinct lobes. Verrucae on all sides of the branches, mostly 0.75 to 1.0 mm. apart. Anthocodial armature of eight points of spindles in converging rows and collaret of short spindles transversely arranged. Axis composed of smooth, irregularly branched spicules and horny substance. Color, in life, bright orange; in dry condition, dirty brown. Sclerites of deep layers of coenenchyma blunt spindles with prominent belts of warts; in superficial layers double clubs or double wheels with smooth, sharply constricted shaft; those at surface with heads unilaterally produced into a pair of granular lobes.

Spicule measurements:
Spindles: 0.1 × 0.04 mm.; 0.08 × 0.045 mm.
Symmetrical double clubs: 0.05 × 0.034 mm.; 0.026 × 0.02 mm.
Asymmetrical double clubs: 0.03 × 0.03 mm.; 0.045 × 0.035 mm.

Locality: Enyu Island, Bikini Atoll, on edge of a large coral knoll in about 45 feet of water, August, 1947.

Specimen: Dry fragments, U.S.N.M. No. 44074.

Remarks: This specimen, of which the U. S. National Museum possesses only fragments, was about 8 feet high when complete, and so large that only one of the branches could be collected. Dr. Robert W. Hiatt, of the University of Hawaii, found it while diving on a submerged reef off Enyu Island. When alive the colony was a bright orange color, according to Dr. Hiatt, but after a few hours in the air it assumed the brownish hue which it still retains. The greater part of the specimen is in the collection of the University of Hawaii.

Stiasny first recognized that Nutting had erred in calling this scleraxonian a plexaurid. However, the calcareous deposits of the axis take a definite spicule form, unlike those of the Plexauridae. In its cortical spiculation it is similar to *S. verriculata,* although the asymmetrical double wheels of the surface layers are not identical with those figured by Aurivillius

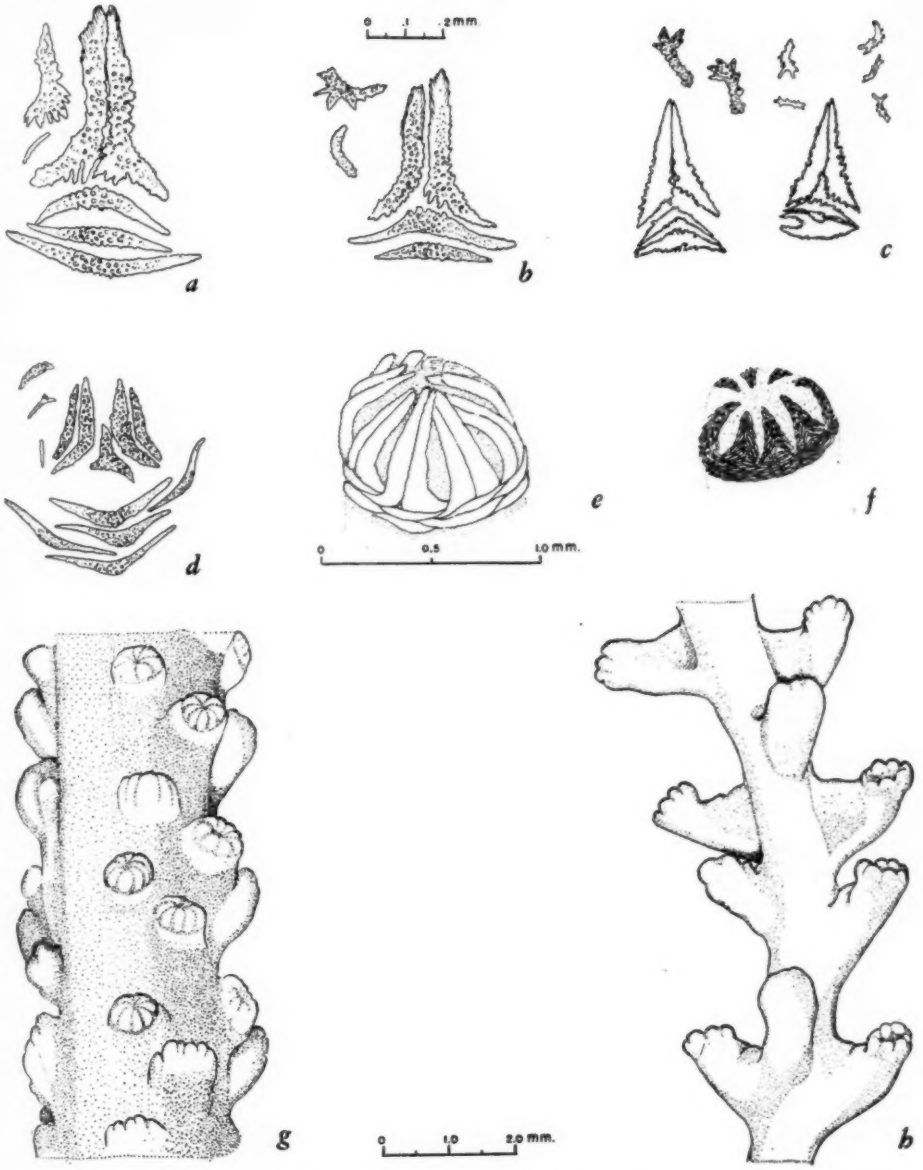

FIG. 1. *a, Villogorgia zimmermani:* Spicules of the opercular point, collaret, tentacles, and pinnules. *b, Villogorgia zimmermani* form *pallida:* Spicules of the opercular point, collaret, tentacles, and pinnules. *c, Villogorgia compressa:* Spicules of the opercular point, collaret, tentacles, and pinnules. *d, Echinogorgia russelli:* Spicules of the opercular point, collaret, tentacles, and pinnules. *e, Paracis orientalis:* Oblique view of retracted zooid with its armature. *f, Suberogorgia mollis:* Oblique view of retracted zooid with its armature. *g, Toeplitzella laevis:* Part of branch, enlarged, showing arrangement of verrucae. *h, Scirpearia erythraea:* Part of the stem, enlarged, showing arrangement of verrucae.

(1931: 20). The manner of branching and anastomosis is quite different, the meshes of *S. mollis* being much longer and more regular than those of *S. verriculata.*

Genus KEROEIDES Wright and Studer

Keroeides koreni Wright and Studer

Pl. 3, fig. 3

Keroeides koreni Wright and Studer 1889: 169, pl. 40, fig. 3.
Keroeides gracilis Whitelegge 1897: 308, pl. 16, figs. 1–5.
Keroeides gracilis + *K. pallida* Hiles 1899: 201, pl. 22, figs. 12–16.
Keroeides gracilis Thomson and Henderson 1905: 287.
Keroeides gracilis + *K. koreni* Thomson and Henderson 1906: 22, pl. 1, figs. 6–7; pl. 4, figs. 1–3.
Keroeides koreni Thomson and Simpson 1909: 167.
Keroeides koreni Kinoshita 1910: 226.
Koroeides [*sic*] *koreni* Nutting 1911: 31, pl. 6, figs. 3, 3a.
Keroeides koreni Kükenthal 1919: 120.
Keroeides koreni Kükenthal 1924: 46.
Keroeides koreni Aurivillius 1931: 38.

Diagnosis: Colony erect, branched in one plane, with occasional anastomosis. Stems round in cross section, 2.5 mm. in diameter; twigs also round, 1.0 mm. in diameter. Sub-conical verrucae 1.0 mm. in width at the base by 1.0 mm. in height, and from 1.5 to 4.0 mm. apart, biserially and often alternately along the sides of the branches. Coenenchyma thin, filled with large fusiform to oval, and sometimes flattened, spicules; zooids armed with smaller spindles. Sclerites bright red in color. Axis composed of smooth, terete spindles, light red in color, joined together by horny matter. Entire colony bright red, axis paler.

Spicule measurements:

Spindles: 1.05 × 0.25 mm.; 0.47 × 0.14 mm.; 0.39 × 0.11 mm.
Ovals: 0.54 × 0.21 mm.
Spindles of the zooids: 0.15 × 0.03 mm.
Spindles of the axis: 0.32 × 0.06 mm.; 0.25 × 0.04 mm.

Locality: Station 12.

Specimen: One, preserved dry, U.S.N.M. No. 44075; branches thereof in alcohol, U.S.N.M. No. 44076.

Remarks: The Resurvey obtained one fine specimen, 127 mm. in height and 105 mm. in maximum width, which agrees very closely with the original and subsequent descriptions.

Genus PARACIS Kükenthal

Paracis squamata (Nutting)

Fig. 6*a–e*; Pl. 1, fig. 1

Acis squamata Nutting 1910*a*: 42, pl. 7, figs. 2, 2a; pl. 20, fig. 50.
Acis squamata Nutting 1912: 81.
Paracis squamata Kükenthal 1924: 158.
Acis squamata Thomson and Dean 1931: 200, pl. 5, fig. 2; pl. 16, fig. 9.
Paracis squamata Aurivillius 1931: 145 (in key only).

Diagnosis: "Colony flabellate, 14.3 cm. in height and with a spread of 4.9 cm. The main stem is round, 3.8 mm. in diameter. 1.6 cm. from its base it gives off a short branch, and from that point to near its distal end it gives off roughly alternate branches, several of which give off branchlets nearly all of which are on one side of the branch. The branches near the distal end of the colony are more symmetrical in their branchings than the more proximal ones. The calyces are borne almost exclusively on the sides and front of the stem and branches, where they are unevenly distributed, varying from .5 mm. to 2.2 mm. in the distance between them.

"The individual calyces are short tubes averaging about 1.5 mm. in height, and about the same in diameter. Their walls are composed of plate-like or scale-like spicules of various shapes; but fitted to each other, although they sometimes overlap somewhat. The ends, or edges, of the distal row form a scalloped border around the calyx margin. There seems to be no regularity whatever in the disposition of these calyx spicules. They are also exceedingly irregular in

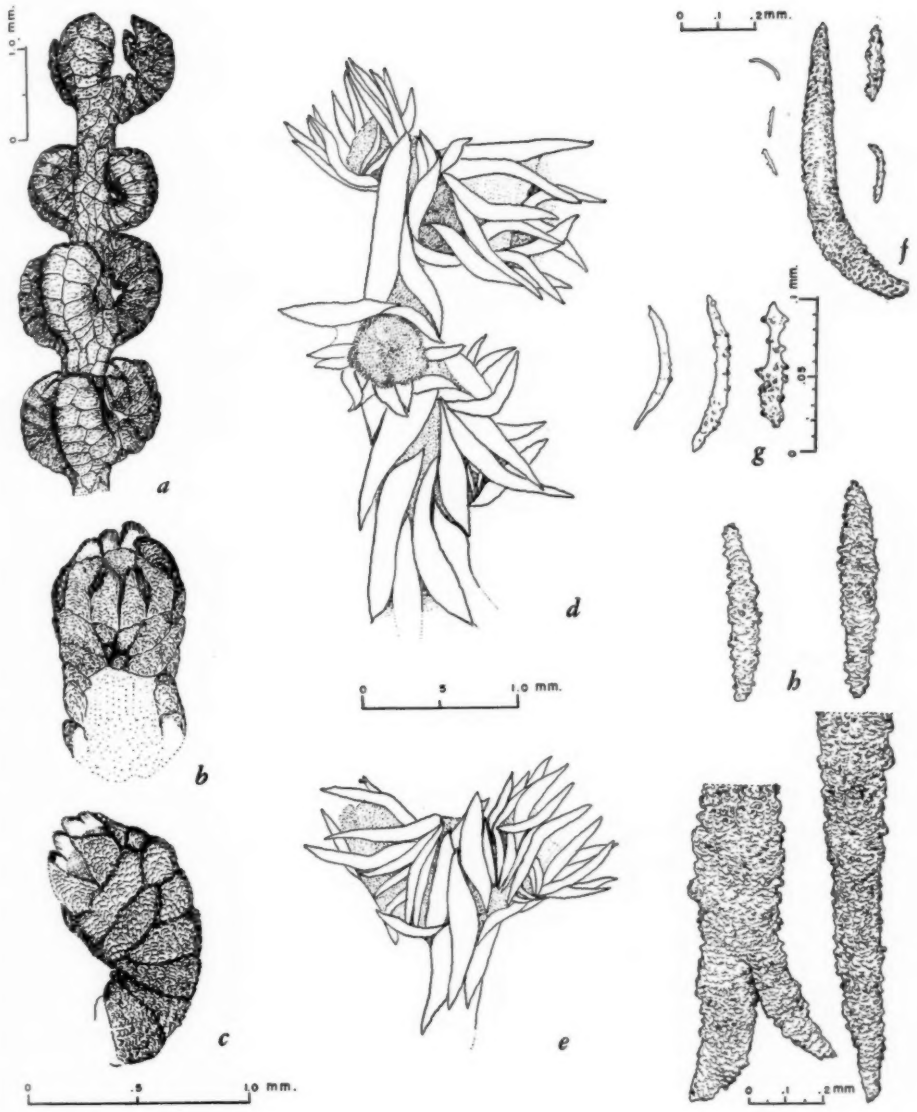

FIG. 2. *a–c, Caligorgia pseudoflabellum: a,* part of twig, enlarged, showing arrangement of the whorls of zooids; *b,* adaxial view of zooid; *c,* lateral view of zooid. *d–h, Muricella englemani: d, e,* parts of twigs, enlarged, showing calyces; *f,* spicules of calyx and tentacles; *g,* spicules of tentacles; *h,* spicules of the coenenchyma.

shape, being squarish oblong with rounded corners, rudely triangular, or irregular polygons of various sorts. The ones on the basal part of the calyx are usually larger than those on the distal part. The polyps are retractile, but it is doubtful if the calyx walls can completely cover the operculum. The latter is composed of relatively heavy spindles or bar-like forms. Two of these are often closely fitted together and curved over a tentacle to form a solid opercular segment or flap.

"Spicules. Some of the largest spicules of the Gorgonacea are found in this species. Those covering the coenenchyma are closely and exactly fitted together along all their contiguous edges. They are squarish or oblong plates of various forms, and attain a length of 5 mm. and a diameter of 2 mm. Typical spindles are rarely seen. The edges of the spicules are often regularly but minutely ctenate, and their surface is covered with fine granules.

"Color. The entire colony is ivory white in alcohol. The axis is light yellowish gray, and the spicules are colorless." (Nutting, 1910*a*.)

To Professor Nutting's description I add: Colony erect, flabellate, branched in one plane. Without anastomosis. Stem and branches round, stems 2.5 mm. in diameter, twigs near their ends about 2.0 mm. Anthocodiae retractile into tubular verrucae which are unevenly distributed over three sides of the stems and branches, i.e., "back" face of the flabellum practically free of zooids. Verrucae 1.5 mm. high and 1.5 mm. wide at base, separated by intervals of from 1.0 to 3.0 mm. Verrucal walls irregularly covered with closely fitted scale-like plates. Anthocodial armature of eight points each composed of two spindles bent sharply outward at proximal end; these spicules quite variable, members of a pair may differ considerably in size. Tentacles armed with small spindles and curved forms furnished with prominent conical processes. Spicules of the coenenchyma oblong or squarish thick plates, closely fitted together. Anthocodial spicules colorless, plates of cortex white.

Spicule measurements:

Plates of the coenenchyma: 2.85 × 1.25 mm.; 0.7 × 0.65 mm.; up to 5.0 × 2.0 mm.

Calyx marginals: 0.6 × 0.35 mm.; 0.69 × 0.49 mm.

Opercular: 0.61 × 0.07 mm.; 0.64 × 0.08 mm.

Tentacular: 0.15 × 0.025 mm.; 0.15 × 0.035 mm.; 0.18 × 0.03 mm.

Locality: Station 30.

Specimen: U.S.N.M. No. 44077, preserved in alcohol.

Remarks: The Resurvey Collection contains a fine specimen of this unmistakable muriceid. It consists of two large flabellate portions arising from an expanded base free of zooids, from which some smaller stems also arise. The secondary branches arise at slightly less than 90° angles, and soon bend upward. Branching is usually, but not always, alternate, chiefly in one plane; the branches do not anastomose. The species has been taken previously only by the "Siboga" and "Albatross."

Paracis orientalis (Ridley)

Figs. 1*e*, 5*a–e*; Pl. 1, fig. 4

Acis orientalis Ridley 1882: 126, pl. 5, figs. 1–6.

Diagnosis: Colony erect, irregularly branched in one plane, without anastomosis; flabellum arising from a distinctly expanded and encrusting base which bears numerous zooids. Stems round in cross section, 2.5 mm. in diameter; twigs, near end, 1.5 to 1.75 mm. in diameter. Anthocodiae retractile into low, tubular to dome-like verrucae, distributed on all sides of the colony, less common on the "back" face. Verrucae vary considerably in size, most commonly 1.0 mm. in diameter by 0.5 mm. or less in height, sometimes 2.0 mm. in basal diameter by over 0.5 mm. in height. Verrucal walls covered with irregular, multispinose scales, latter, at distal margin, reduced to simple spine with flattened, tubercular base. Anthocodial armature consisting of eight points, each formed of two contiguous bent spindles, and two curved spindles placed transversely beneath each point, to-

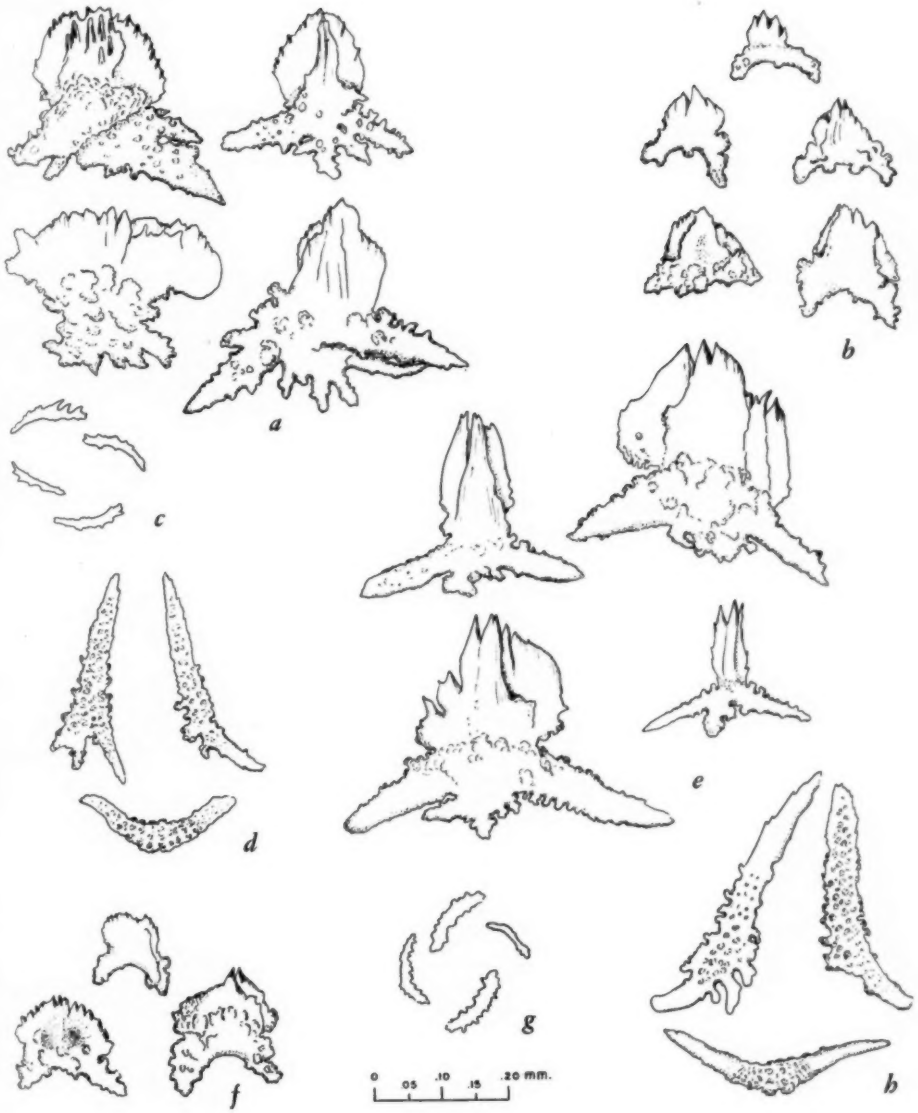

FIG. 3. *a–d, Villogorgia zimmermani* form *pallida: a,* spicules of the calyces; *b,* of the coenenchyma; *c,* of the tentacles; *d,* operculum and collaret. *e–h, Villogorgia zimmermani: e,* spicules of the calyces; *f,* of the coenenchyma; *g,* of the tentacles; *h,* operculum and collaret.

gether forming collaret ring. Tentacles further provided with curved, spinose, club-like spicules, and pinnulae with smaller straight spindles. Coenenchyma covered with irregular elongate plates very closely fitted as in mosaic. These ornamented with low protuberances, quite spinose near the calyces. Axis horny, flexible, yellowish-brown in color. Spicules of anthocodiae colorless, those of stems grayish white. Colony as a whole brownish-gray in color, with verrucae darker.

Spicule measurements:

Coenenchyma: 0.32 × 0.11 mm.; 0.39 × 0.15 mm.; 0.38 × 0.15 mm.; 0.41 × 0.14 mm.; 0.94 × 0.42 mm.; 1.5 × 0.5 mm.

Calyx marginals: 0.67 × 0.24 mm.; 0.66 × 0.24 mm.; 0.45 × 0.10 mm.

Opercular: 0.665 × 0.1 mm.; 0.565 × 0.08 mm.; 0.3 × 0.065 mm.

Tentacular: 0.36 × 0.06 mm.; 0.36 × 0.065 mm.; 0.36 × 0.05 mm.

Collaret: 0.6 × 0.1 mm.; 0.5 × 0.05 mm.; 0.42 × 0.035 mm.; 0.415 × 0.06 mm.

Locality: Station 30.

Specimens: U.S.N.M. No. 44078, preserved in alcohol.

Remarks: The Resurvey Collection contains a moderately large example of this species (85 mm. in height and 77 mm. in width) consisting of two stems which arise from the spreading, encrusting base covering a branch of coral. The lateral branches arise at intervals of 10 to 15 mm. along the main stem, occasionally more or less. There is also a small colony 35 mm. in height which differs in no essential detail. It may be observed that this species will not key out satisfactorily in Kükenthal's key to the genus *Paracis*.

Genus MURICELLA A. E. Verrill

Muricella englemani new species

Fig. 2*d–h*; Pl. 2, fig. 1

Diagnosis: Colony erect, spreading, flabellate, branched in one plane. Anastomosis frequent and irregular. Branches sinuous, knotty in places, with tendency to flatten at almost any angle to the plane of branching, varying with position in the colony. Main stem, before dividing, and smallest twigs, round in cross section. Twigs tend toward an opposite arrangement on branches. Larger branches 1.5 × 3.0 mm. in diameter, twigs 1.0 mm. Zooids small, on all sides of the colony, in short tubular verrucae, latter 1.0 mm. high by 0.7 mm. wide. Verrucal margin formed of eight points of one or more pairs of bent spindles which do not close over the tentacles in retraction. Tentacles with small, often curved, sparsely warted spindles. Coenenchyma thin, covered with layer of large, often twisted spindles, irregularly and densely warted on all sides; deeper layer of generally smaller spindles between them. Axis completely horny, dark brown or black in color, visible through crust-like layer of cortical spicules.

Spicule measurements:

Spindles from verrucal points: 0.58 × 0.06 mm.; 0.87 × 0.10 mm.

Spindles from tentacles: 0.16 × 0.02 mm.; 0.21 × 0.05 mm.; 0.08 × 0.02 mm.

Spindles from coenenchyma: 0.60 × 0.11 mm.; 0.49 × 0.09 mm.; 2.07 × 0.27 mm.

Locality: Station 9.

Specimen: The holotype, dry, U.S.N.M. No. 44079; branches of same, in alcohol, U.S.N.M. No. 44080.

Remarks: The type is a large, nearly perfect colony 260 mm. in height by 400 mm. in width. It is attached by a trunk 5 mm. in diameter to a piece of coral rock. The base is not expanded.

Genus ECHINOGORGIA Kölliker

Echinogorgia russelli new species

Figs. 1*d*, 4*c*; Pl. 3, fig. 4

Diagnosis: Colony erect, flabellate, branched in one plane. Branching alternate to irregular, with frequent anastomosis, forming open network. End twigs 1.25 to 1.5 mm. in diameter, bent upward, somewhat thickened at tips. Larger branches 2.0 to 2.5 mm. in diameter, flattened at right angles to plane of branching. Anthocodiae retractile into low, dome-like verrucae, 1 mm. in diameter by 0.5 mm. or less in height, closely placed on all sides of branches and twigs,

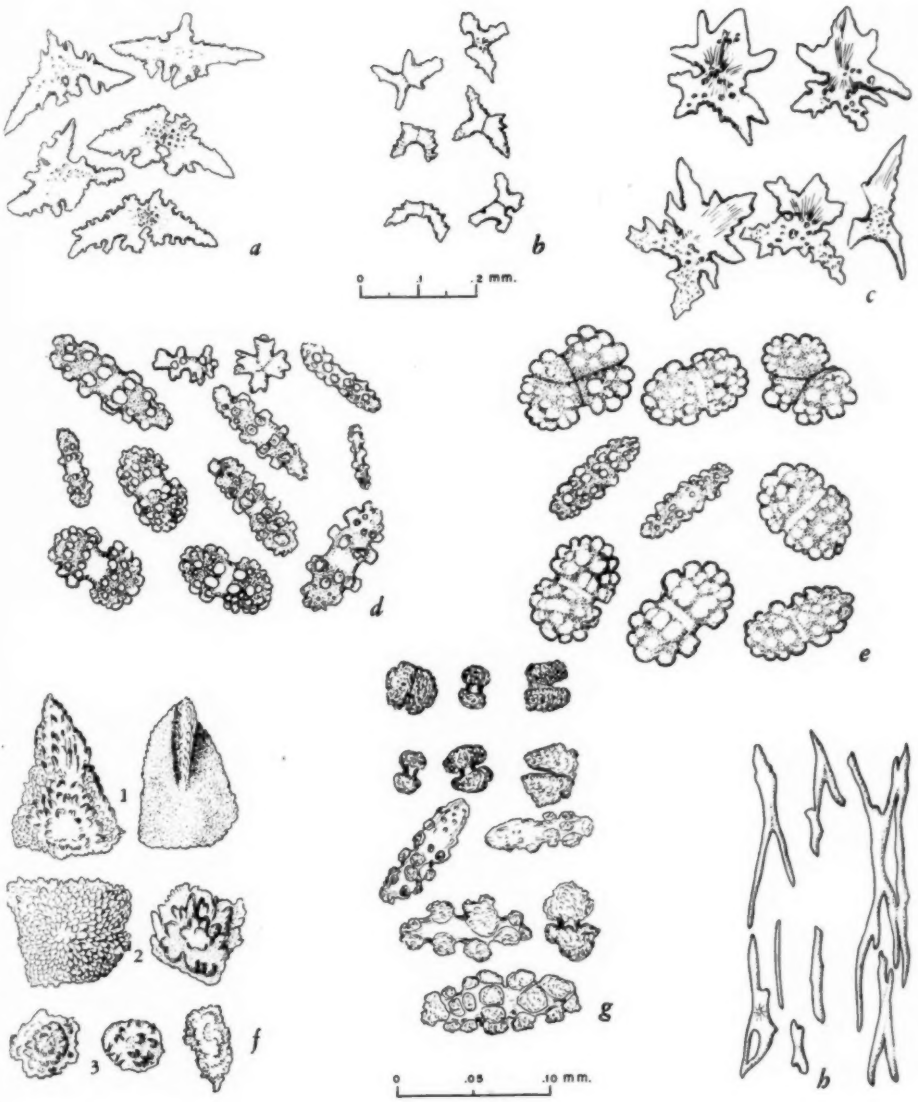

FIG. 4. *a, b, Villogorgia compressa: a,* spicules of the calyces; *b,* of the coenenchyma. *c. Echinogorgia russelli:* Spicules of the calyces. *d, Scirpearia erythraea:* Spicules. *e, Toeplitzella laevis:* Spicules. *f, Caligorgia pseudoflabellum:* f_1, spicules of the operculum; f_2, of the marginal row; f_3, the coenenchyma. *g, h, Suberogorgia mollis: g,* spicules of the coenenchyma, the double clubs from the surface, and the warted spindles from the deeper layer; *h,* spicules of the axis. (Upper scale applies to *a, b, c, f, h;* lower to *d, e.*)

commonly in spiral arrangement. Anthocodial armature eight points, formed by two or more pairs of bent spindles arranged *en chevron*, with one or two smaller spicules filling basal interspace; prominent collaret of four or five rows of strongly curved, transversely arranged spindles below points. Coenenchyma and verrucae filled with multiradiate forms and "Stachelkeulen" of the type shown by Hickson (1932: 481, text fig. 6a, b). Leaves of these spicules project from surface of coenenchyma and verrucal walls rendering these surfaces prickly and verrucal orifice serrate. Axis dark brown, horny, without calcareous deposits. Color of colony light brick-red, sclerites light reddish or orange; opercular spindles colorless.

Spicule measurements:

"Stachelkeulen": 0.21 × 0.19 mm.; 0.3 × 0.15 mm.; 0.2 × 0.175 mm.

Radiate forms: 0.24 × 0.15 mm.; 0.21 × 0.16 mm.

Spindle of opercular point: 0.25 × 0.05 mm.

Spindle of collaret: 0.31 × 0.02 mm.

Locality: Stations 9, 23.

Specimens: The holotype, dry, U.S.N.M. No. 44082; portions in alcohol U.S.N.M. No. 44083; paratypes, dry, U.S.N.M. No. 44081.

Remarks: The Resurvey Collection contains three specimens which measure as follows:

The holotype: 190 mm. high, 114 mm. wide (Sta. 23).

The paratypes: 190 mm. high, 207 mm. wide (Sta. 9); 86 mm. high, 36 mm. wide (Sta. 9).

This species appears to have been undescribed heretofore, and I take pleasure in dedicating it to Dr. R. Dana Russell, through whose efforts the specimens were obtained.

Genus VILLOGORGIA Duchassaing and Michelotti

Villogorgia zimmermani new species

Figs. 1*a*, 3*e–b*; Pl. 3, fig. 1

Diagnosis: Colony erect, flabellate, branched in one plane; without anastomosis. Branching alternate, opposite, and sometimes unilateral for considerable distances. Stems round, 3.0 mm. in diameter; branches 1.5 mm.; twigs, near the ends, 1.0 mm. Anthocodiae retractile into short, tubular verrucae, points of the operculum usually not entirely withdrawn into it. Verrucae, from 1.0 to 1.5 mm. in width by slightly less in height, scattered irregularly over three sides of stems and branches, less abundantly on fourth. Calyces usually about 2.0 to 2.5 mm. apart, closest toward tips of twigs; two on twig ends usually opposed. Anthocodial armature of eight points, each formed by two longitudinally arranged contiguous spindles bent outward at proximal end; a collaret ring composed of two curved spindles transversely placed beneath each point. Verrucae thickly beset with *"Acamptogorgia*-type" (Nutting, 1910*a*) spicules, whose foliate and spinose ends project from surface and impart a rugose appearance. Coenenchyma filled with smaller forms with projecting foliaceous part, and two to four root-like, thickly warted processes. All sclerites rose-purple, those of operculum much paler. Axis horny, with no calcareous deposits. Color of colony deep wine-purple, with spaces between spicule folia darker; zooids brownish; axis light brown.

Spicule measurements:

Opercular spindles: 0.35 × 0.09 mm.; 0.33 × 0.06 mm.

Collaret spindles: 0.27 × 0.055 mm.; 0.25 × 0.04 mm.

Foliate spicules of the verrucae and coenenchyma:

Width across roots	Diameter of roots at base	Height of folia	Width of folia
	VERRUCAE		
0.32	0.06	0.145	0.09
0.45	0.08	0.12	0.17
0.41	0.05	0.15	0.15
0.30	0.06	0.145	0.19
0.39	0.05	0.215	0.10
0.63	0.12	0.23	0.13
0.45	0.10	0.29	0.16
	COENENCHYMA		
0.18	0.04	0.10	0.16
0.19	0.06	0.11	0.175
0.13	0.35	0.06	0.09

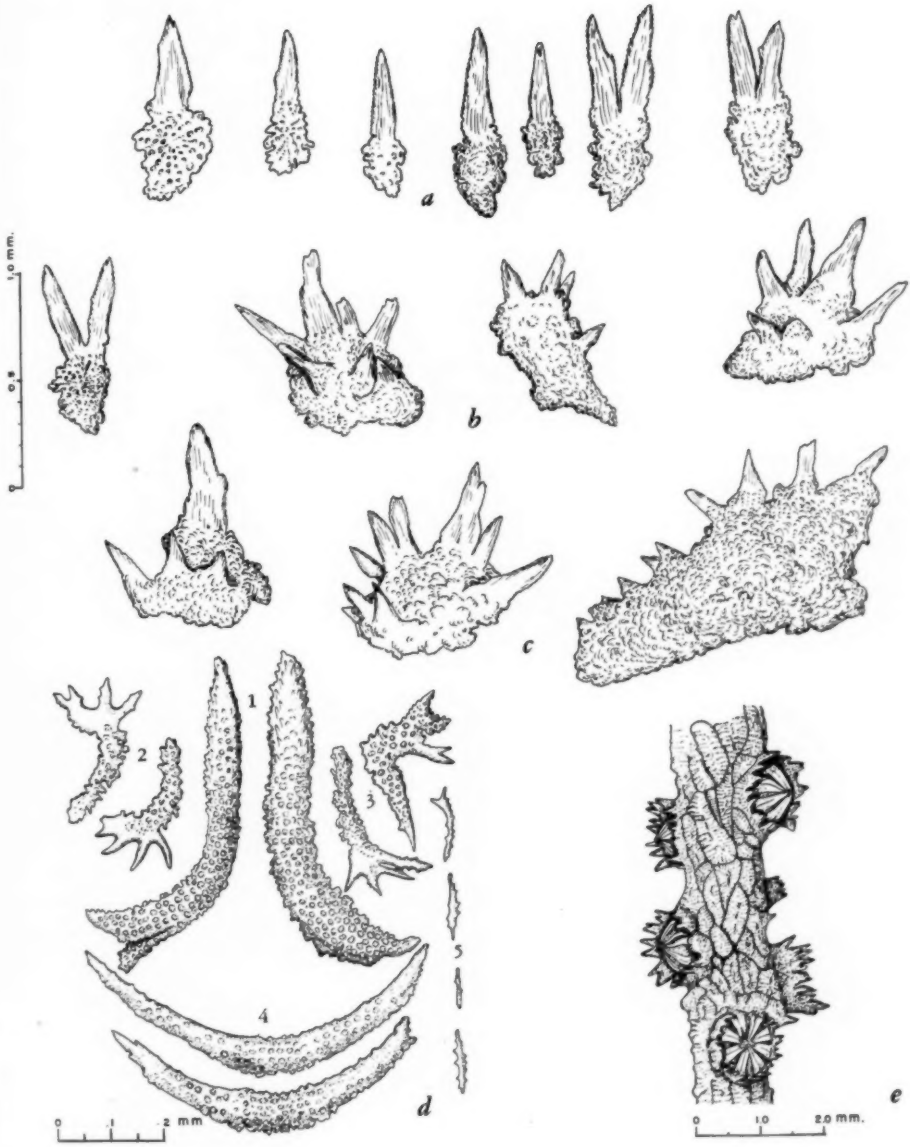

FIG. 5. *a–e, Paracis orientalis: a,* spicules of the calicular margin; *b,* of the verrucal wall; *c,* of the verrucal base and adjacent cortex; *d,* of the anthocodial armature, including one of the points (1), clubs from the tentacles (2 and 3), curved spindles of the collaret (4), and spindles of the pinnules (5); *e,* part of a twig enlarged to show the arrangement of verrucae.

Locality: Station 30.

Specimens: The holotype, U.S.N.M. No. 44084, and 11 paratypes, U.S.N.M. No. 44085, preserved in alcohol.

Remarks: The specimens represented in the Resurvey Collection measure as follows:

Holotype: 145 × 120 mm.
Paratypes: 150 × 120 mm.
125 × 90 mm.
75 × 115 mm.
45 × 22 mm.
12 × 18 mm.
21 × 8 mm.
80 × 57 mm.
47 × 45 mm.
70 × 45 mm.
50 × 42 mm.
40 × 25 mm.

In the measurements given above, the height is listed first. The third, fourth, fifth, and sixth paratypes are all attached to the same fragment of coral, and show the variation in shape of colonies at different ages. In a fully adult colony, the stem measurements are as follows: Stem, diameter 3.0 mm.; branch, 1.5 mm.; twig, 1.0 mm. In small specimens, all the branches are about 1.0 mm. in diameter.

The sclerites of this species, when carefully cleaned and examined under a dissecting microscope, are among the most beautiful of all alcyonarian spicules. The accompanying illustrations leave much to be desired in conveying their crystalline appearance.

It is with pleasure that I name this new species for Fred Zimmerman, whose sincere enthusiasm and faithful assistance were great assets on many collecting trips.

Villogorgia zimmermani form ***pallida*** new
Figs. 1*b*, 3*a-d*; Pl. 3, fig. 2

Diagnosis: Similar to *V. zimmermani* s.s., except: color, pale yellowish-brown, with colorless spicules; colony less robust, stems measuring 2.5 mm. in diameter, branches 1.25, and twigs 0.75; verrucae also somewhat smaller. Spicules same size as in typical form, but completely without rose-purple color. Operculum identical to that of typical form.

Locality: Station 30.

Specimen: The holotype, U.S.N.M. No. 44086.

Remarks: Although this specimen is not specifically distinct, it differs so markedly in color, and in its general slenderness, that it seems advisable to separate it from *V. zimmermani* as a form.

Villogorgia compressa Hiles
Figs. 1*c*, 4*a–b*; Pl. 2, fig. 2

Villogorgia compressa Hiles 1899: 200, pl. 22, fig. 7.
Villogorgia compressa Nutting 1910*a*: 71.
Brandella compressa Kükenthal 1924: 218.
Villogorgia compressa Aurivillius 1931: 225.

Diagnosis: Colony erect, flabellate, branched in one plane, with frequent anastomosis of both large and small branches. Branching irregular. Main stem oval in cross section, 1.0 by 2.0 mm. in diameter, flattened at right angles to plane of branching. After first major division of trunk, stems strongly compressed, 0.75 by 1.75 mm. in diameter; end twigs round, 0.5 mm. in diameter. Anthocodiae retract into prominent tubular verrucae set at right angles to stems. Verrucae from 0.75 to 1.0 mm. in height, slightly less in width, irregularly scattered over colony, less abundant on "rear face." End twigs usually with opposed pair of zooids. Axis horny, light brown, becoming paler distally. Color of dry colony dirty brown. Sclerites of verrucae horizontally arranged, with a short projecting portion of one or two short, finger-like processes, and with two flattened, branched roots. Sclerites of coenenchyma quadriradiate forms of smaller size. Anthocodial armature eight pairs of flattened spicules arranged longitudinally and forming eight points; transverse rows beneath these merge with transverse verrucal spicules, hence collaret without well-defined proximal boundary.

Spicule measurements:

Spicules of verrucae: 0.25 × 0.01 mm.; 0.24 × 0.01 mm.; 0.26 × 0.125 mm.

Quadriradiates of coenenchyma: 0.15 × 0.09 mm.; 0.10 × 0.06 mm.; 0.158 × 0.1 mm.
Opercular points: 0.33 × 0.06 mm.; 0.36 × 0.07 mm.; 0.30 × 0.055 mm.
Transverse: 0.20 × 0.04 mm.; 0.20 × 0.07 mm.; 0.25 × 0.05 mm.
Spinose clubs of tentacles: 0.16 (length) × 0.10 (across spines) mm; 0.155 × 0.09 mm.; 0.10 × 0.055 mm.

Locality: Station 9.

Specimen: U.S.N.M. No. 44087 (dry), 44088 (branches in alcohol).

Remarks: The one specimen obtained, which is 145 mm. high and 193 mm. wide, agrees well with Miss Hiles' original description and figures.

Genus CALIGORGIA J. E. Gray

Caligorgia pseudoflabellum new species

Figs. 2*a–c*, 4*f*; Pl. 4, fig. 2

Caligorgia flabellum Nutting 1912: 60.
Not *Prymnoa flabellum* Ehrenberg 1834: 358.
Not *Primnoa flabellum* Kölliker 1865: 135, pl. 17, fig. 11.

Diagnosis: Colony erect, alternate-pinnately branched in one plane. Zooids in whorls of 3 or 4, rarely 5, on twigs; 28–32 whorls in 4 cm. twig length. Individual zooids ± 1.25 mm. high, clavate, bent inward, covered with closely fitted spicules heavily warted on outer surfaces. Abaxial rows with eight scales; outer lateral rows reduced to two; adaxial rows two, very small. Operculum of eight scales, adaxials smallest; rather elongate, with single broadly rounded, crenulate distal projection. Coenenchyma with irregular scales. Color creamy white. Axis calcareous, finely striate longitudinally, with metallic golden luster.

Spicule measurements:
Opercular scales: 0.32 × 0.23 mm.; 0.29 × 0.19 mm.
Body scales: 0.27 × 0.20 mm.; 0.20 × 0.18 mm.
Coenenchyma scales: 0.13 × 0.15 mm.; 0.20 × 0.15 mm.; 0.11 × 0.13 mm.; 0.17 × 0.09 mm.; 0.11 × 0.17 mm.

Locality: Station 30.

Specimen: The holotype, U.S.N.M. No. 44089, in alcohol.

Remarks: The Resurvey Collection includes an incomplete specimen which is probably a branch from a very large colony. *Caligorgia pseudoflabellum* is identical with the species taken by the "Albatross" in Japanese waters and referred erroneously to *Caligorgia flabellum* by Professor Nutting. It differs markedly from the specimens of *C. flabellum* which Kinoshita (1908: 35) described, as can be seen from the tabulated comparison on this page.

Genus SCIRPEARIA G. Cuvier

Scirpearia erythraea Kükenthal

Figs. 1*b*, 4*d*; Pl. 1, fig. 3

Scirpearia erythraea Kükenthal 1913: 26, figs. 21, 22; pl. 3, figs. 8–9.
Scirpearia erythraea Kükenthal 1924: 370.
Scirpearia erythraea Toeplitz 1929: 302.
Not *Scirpearia erythraea* Stiasny 1940*b*: 158, 171, pl. 1, fig. 5.

Diagnosis: Colony unbranched, flagelliform, arising from a somewhat spreading base. Primary longitudinal canals two in number. Verrucae prominent, usually somewhat bent, arranged in two series, each of two approximately alternating rows of zooids; series separated by

	C. flabellum	"Albatross" specimens	Resurvey specimen
No. twigs per cm. branch length	8–18	18	14–16
Angle of origin of twigs	30°–40°	30°–40°	30°–40°
Length of twigs	10–20 cm.	2.5–5.0 cm.	2.5–5.0 cm.
No. whorls per 4 cm. twig length	15–20	28–32	28–32
No. polyps per whorl	3–8	3–5	3–5
Length of polyps	1.5–2.0 mm.	2.0 mm.	1.25 mm.

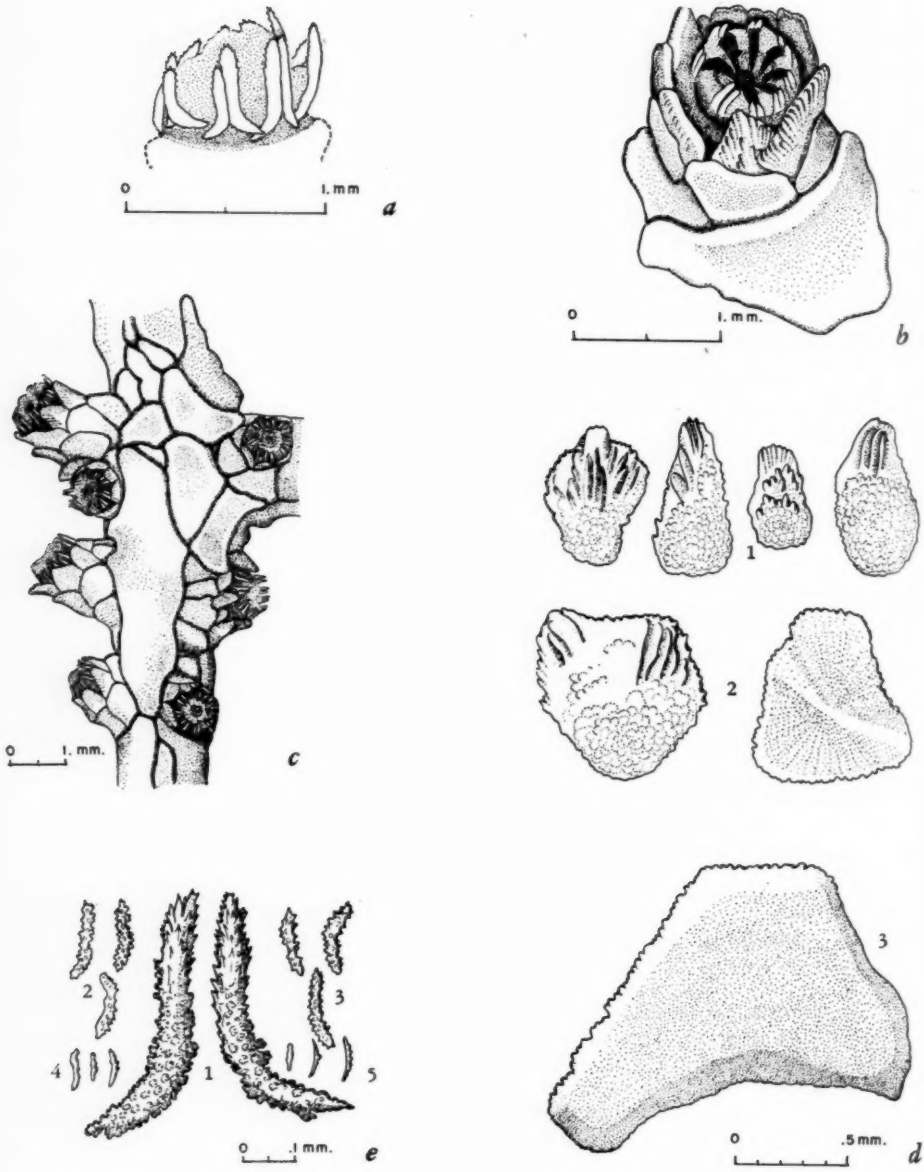

FIG. 6. *a–e, Paracis squamata: a,* side view of retracted zooid removed from calyx to show anthocodial armature; *b,* single calyx with retracted zooid; *c,* a twig enlarged to show arrangement of calyces; *d,* spicules, including spicules of the calicular margin (1), of the verrucal wall (2), and of the verrucal base (3); *e,* spicules, including one of the opercular points (1), spindles of the tentacles (2 and 3), and spindles of the pinnules (4 and 5).

barren areas corresponding to two primary canals. Verrucae absent from lower part of colony. Proximal zooids on colony very low, increasing in height distally, 2 mm. tall near middle of colony. Axis slender, calcified, with prominent concentric rings. Sclerites of verrucae mostly rather long, fairly stout, double spindles with low warts and more or less pronounced smooth girdle. Sclerites of coenenchyma symmetrical double clubs with prominent belts of warts. Color orange-ochraceous, tips of verrucae darker.

Spicule measurements:

Verrucae: 0.08 × 0.025 mm.; 0.075 × 0.025 mm.; 0.095 × 0.031 mm.

Coenenchyma: 0.06 × 0.035 mm.; 0.061 × 0.037 mm.; 0.062 × 0.04 mm.

Locality: Station 9.

Specimens: One perfect, one damaged, U.S.N.M. No. 44090.

Remarks: The collection contains two specimens of this gorgonellid which agree satisfactorily with Kükenthal's diagnosis and figures. The largest, broken at the tip, is 235 mm. long, with a diameter of 2.5 mm. at the base and 1.0 mm. at the upper end. The smaller, and complete, colony is 175 mm. high with a stem diameter of 1.5 mm. at the base tapering to about 0.5 mm. at the tip. Both are attached to fragments of rocks by slightly spreading bases. In the large colony, the verrucae are directed upward, especially toward the tip, as shown in Figure 1*b*, whereas in the smaller, they are bent downward. Although Kükenthal's species was described from the Red Sea, the Bikini examples agree so well with his description that there seems to be no need for separation.

Genus TOEPLITZELLA Deichmann

Toeplitzella laevis (Verrill)

Figs. 1*g*, 4*e*; Pl. 1, fig. 2

Juncella laevis A. E. Verrill 1866: 189.

Juncella laevis + *Scirpearia furcata* + *Scirpearia furcata* var. *robusta* + *Scirpearia robusta* (part) J. J. Simpson 1910: 306, 339, 357.

Ellisella laevis Stiasny 1940*b*: 170.

For detailed list of references, see Kükenthal 1924: 366.

Diagnosis: Colony sparsely branched. End twigs long and whip-like, 2.5 mm. in diameter near base. Anthocodiae retractile into dome-like, upturned verrucae as much as 0.5 mm. in height, arranged in two series along stems, each series of three or four alternating rows of zooids. Series separated by bare tracts corresponding to primary longitudinal canals. Coenenchyma comparatively thick, filled with double clubs whose heads have rather smooth warts. Axis gray-brown, longitudinally striate, highly calcareous, with conspicuous concentric rings. Color plain orange-red, spicules light orange.

Spicule measurements:

Double clubs: 0.07 × 0.025 mm.; 0.075 × 0.048 mm.; 0.07 × 0.044 mm.

Double spindles: 0.07 × 0.025 mm.; 0.071 × 0.026 mm.

Locality: Station 9.

Specimen: U.S.N.M. No. 44091, in alcohol.

Remarks: The Resurvey Collection contains a damaged specimen which was probably more than 18 inches in height when complete. The colony is simply forked; zooids are absent below the fork, and most of the coenenchyma is missing on the trunk.

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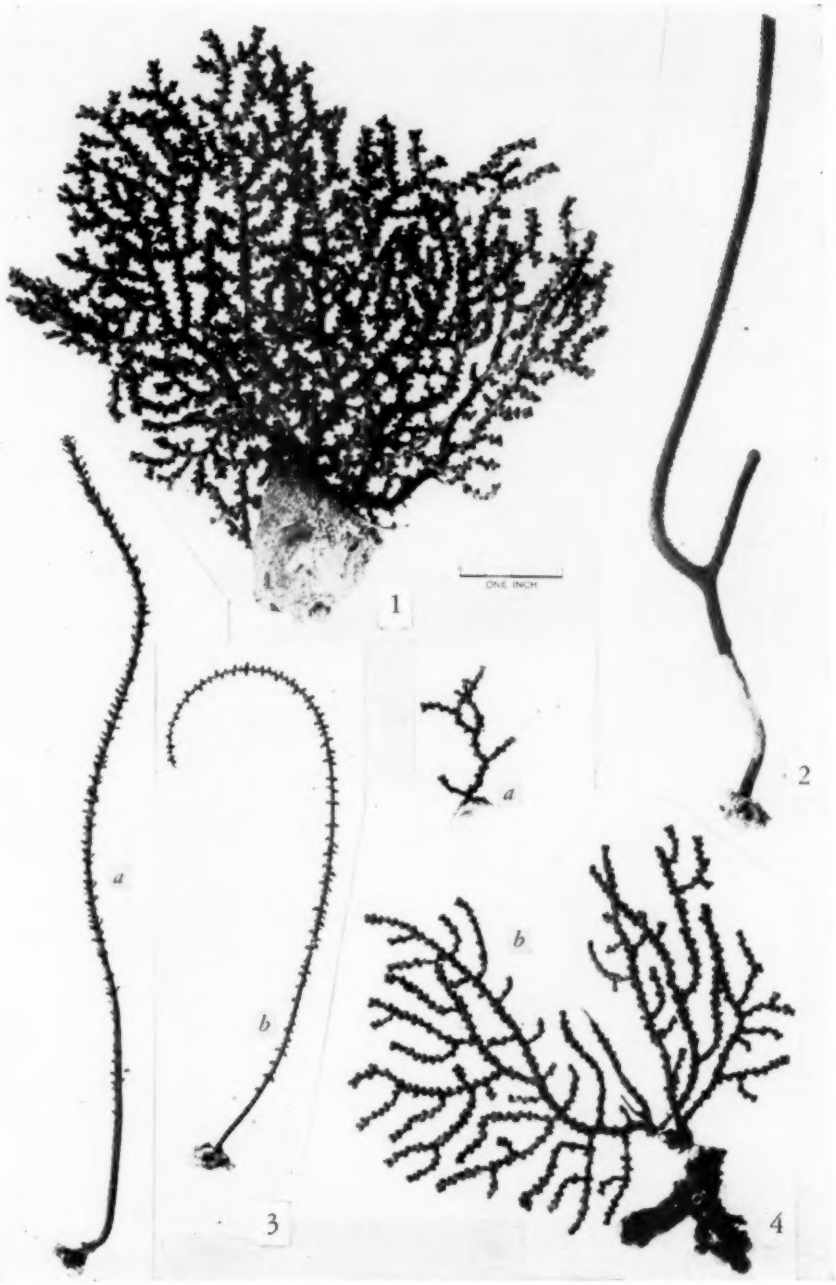

ALCYONARIA PLATE 1.

FIG. 1. *Paracis squamata.*
FIG. 2. *Toeplitzella laevis.*
FIG. 3. *Scirpearia erythraea.* Two colonies.
FIG. 4. *Paracis orientalis.* Two colonies.

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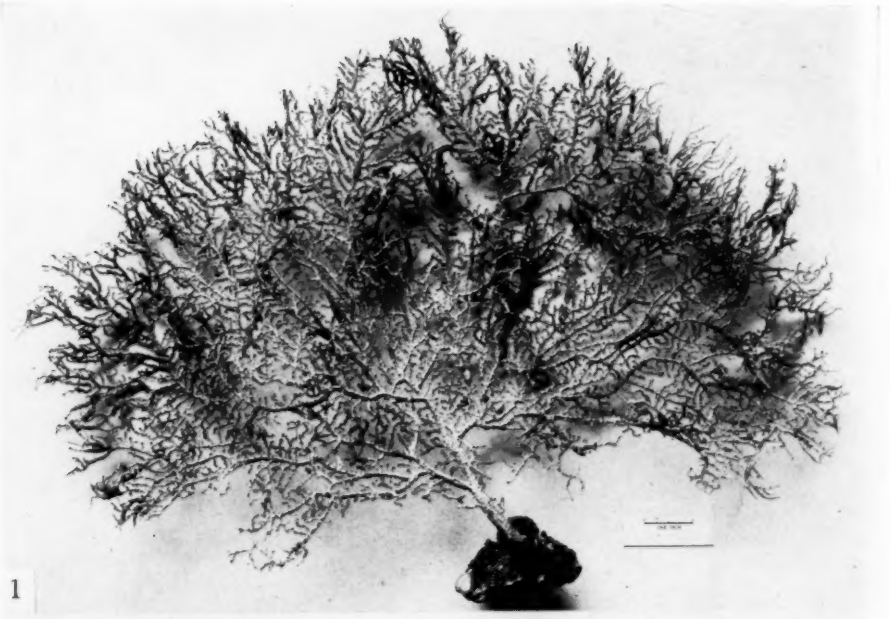

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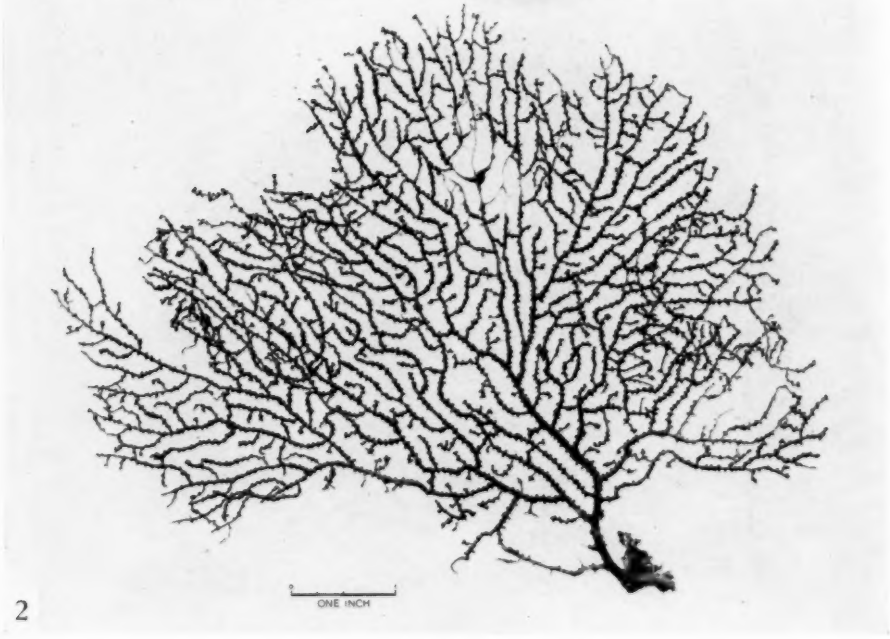

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ALCYONARIA PLATE 2.

FIG. 1. *Muricella englemani.* The holotype. FIG. 2. *Villogorgia compressa.*

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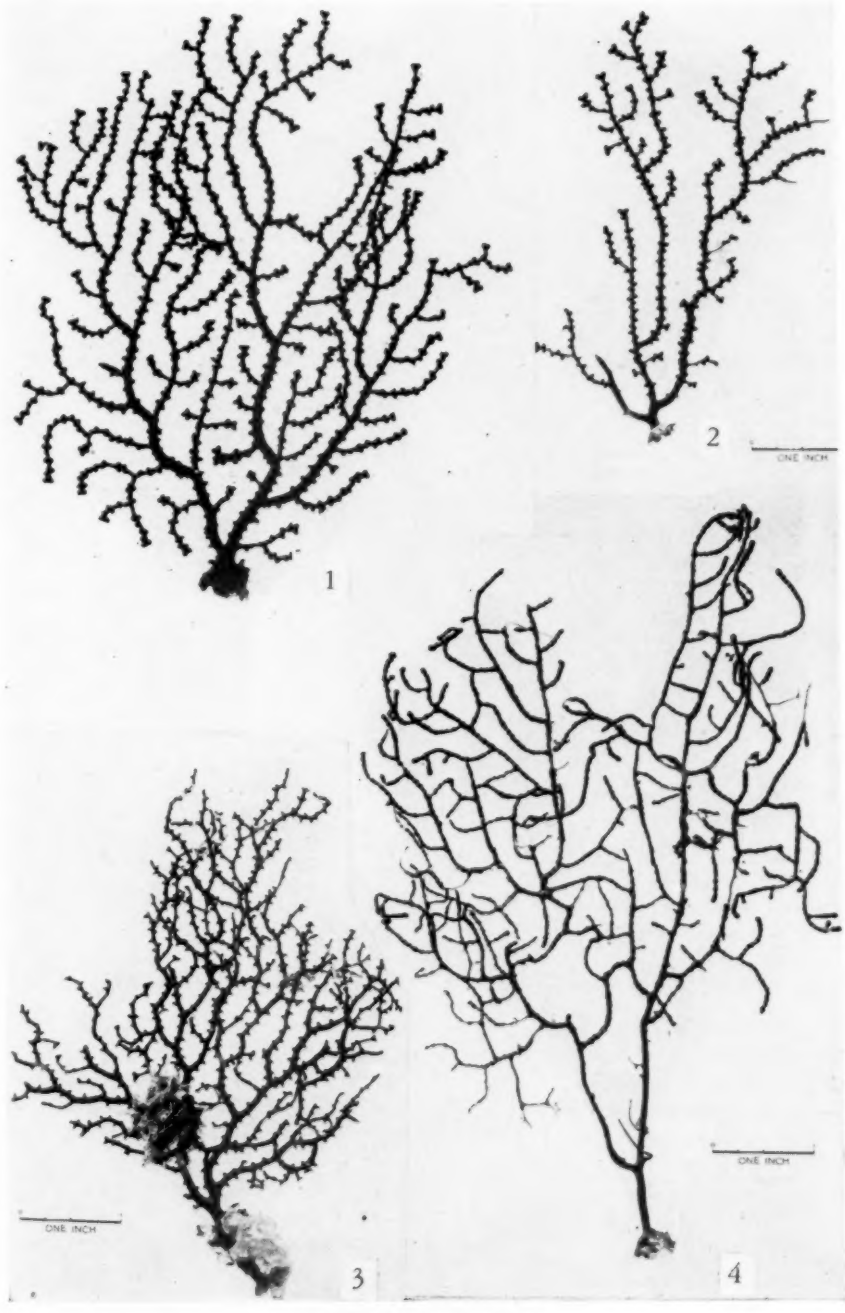

ALCYONARIA PLATE 3.

FIG. 1. *Villogorgia zimmermani.* The holotype.
FIG. 2. *Villogorgia zimmermani* form *pallida.* The holotype.
FIG. 3. *Keroeides koreni.*
FIG. 4. *Echinogorgia russelli.* The holotype.

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ALCYONARIA PLATE 4.

FIG. 1. *Suberogorgia mollis.* FIG. 2. *Caligorgia pseudoflabellum.* The holotype.

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(OFFICIAL PHOTOGRAPHS BY THE SMITHSONIAN INSTITUTION.)

A Review of Concepts in Hawaiian Climatology[1]

LUNA B. LEOPOLD AND C. K. STIDD[2]

IN HAWAII, which is noted for its equable climate, the lack of great variations between seasons often obscures the importance of day-to-day and geographic variations in weather.

Hawaii owes its relatively uniform climate to its position with respect to the sub-tropical high pressure cell and accompanying ocean currents. The rugged topography causes salient orographic rainfall patterns. The variations in annual rainfall through short horizontal distances are common knowledge among residents of Hawaii. Areas in the mountains immediately behind Honolulu receive up to 160 inches annually, while at the seashore, 5.5 miles away from the mountains, less than 15 inches is recorded. On Kauai, the annual mean varies from 450 to 20 inches in a horizontal distance of 12 miles.

The changes of greatest economic importance, surprisingly enough, are those that occur between consecutive months and between consecutive years. The growing of pineapples and of sugar cane represents the two most important industries in the Hawaiian Islands. These industries, which utilize a large proportion of the arable land in the rainfall zone between 20 and 100 inches, have found that the wide variations in rainfall from the mean in consecutive months and consecutive years constitute one of the most critical risks in their operations.

A program of research aimed at improvement of short- and long-range forecasts has been initiated by the sugar and pineapple industries of Hawaii in cooperation with the U. S. Weather Bureau. In the course of the work it has become clear that the investigations of Hawaiian climate in the past have been of such diverse character that a summary of present knowledge would be of assistance to those workers concerned with climatologic problems of these latitudes.

STORM TYPES

A clear-cut definition of storm types is probably somewhat more difficult than it was thought to be in the past. Besides orographic rain resulting from lifting of the trade winds, Jones (1939) stressed the importance of what he called "cyclonic activity." He asserted that what is locally known as "kona weather" in Hawaii is associated with "cyclonic" or frontal activity. The word *kona,* interpreted as leeward, bears the connotation of winds from south or west (leeward with respect to the normal trade winds). Kona weather has also been described by Daingerfield (1921) and by Leopold (1948).

Jones pictured the periods of heavy rainfall as frontal passages of the temperate latitude type. Later work has shown that many disturbances, particularly in summer, are of the subtropical character as defined by Riehl (1945). During periods when the semi-permanent anticyclone of the eastern Pacific is strong, Hawaii derives rainfall from easterly waves—low pressure troughs moving toward the west in the trade wind current. Riehl (MS.) states that "weather conditions in winter are

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marked by frequent interaction between wave troughs and ridges in the polar westerlies and tropical perturbations. Especially the larger amounts of rainfall over Hawaii seem to occur mainly in periods of such interaction, while uncomplicated passages of extratropical fronts account for many of the smaller rains. Interaction between disturbances of high and low latitudes apparently is the most potent rain-producing factor throughout the trade wind belt."

In describing cyclonic storms, Jones pictured the cloud types producing winter rains as comparable to middle latitude frontal cloud systems. This is true infrequently. Hawaii seldom experiences a complete overcast of altostratus or nimbostratus clouds. In a large percentage of storm periods, the cloud systems are more like those described by Riehl (1945) in the Caribbean. On rainy days over the ocean the masses of cumulus are larger and higher than usual, built up into congestus and, occasionally, cumulonimbus clouds. Patches of altostratus are usually associated with these cumulus masses, with occasional cirrus and altocumulus clouds. Over the islands, orographic lifting assists in cloud development, and the coalescing cumuli, viewed from below, often resemble nimbostratus. From afar it can be seen, however, that only segments of an island are under a complete overcast.

In summary, the rainfall usually comes from large but discrete cloud masses mostly of cumuliform type. A rainy day is characterized by increased size and number of cumuliform clouds. These changes result from horizontal convergence to the east (the rear) of the axis of an easterly wave and in association with a trough in a westerly current.

STORM TYPES IN RELATION TO RAINFALL

Studies of weather types correlated with rainfall amounts in Hawaii have been made by Huddleston (MS.) and by Wallen and Yeh (MS.). In both cases the authors used the Northern Hemisphere Surface Synoptic Chart Series. Huddleston used the precipitation recorded at Honolulu and the CIT–AAF[3] classification system (1942). He also had available the 3 km. maps accompanying the Northern Hemisphere surface charts.

Huddleston showed that the best correlations with Honolulu rainfall were obtained with a type he called "No. 31," characterized by "purely zonal flow at the surface" with a series of cyclones moving eastward along the Aleutian chain. The 3 km. level is characterized by "weak circulation with the base of the upper trough extending as far south as the Hawaiian Islands . . . ." Though his explanation is not very clear, his map gives the impression that the situation involves the passage over Hawaii of a polar trough of the type described by Riehl (1945). Huddleston's second important rain-producing type is his No. 22, "Meridional circulation . . . [with a] well developed Pacific High" positioned over the ocean 20° off the Oregon coast, and a "semi-stationary low center" northeast of Hawaii at about 30° N., 150° W. The abnormally high latitude position of the Pacific High is associated with a low index, and some frontal systems or troughs may move at relatively low latitudes over Johnston Island and Hawaii, stagnating in the semi-stationary trough northeast of Hawaii. The passage of these troughs over Hawaii would account for the correlation of the map-type with rainfall.

Wallen and Yeh (MS.) set up a surface map-type classification scheme which expressed the geographic relation of frontal systems and high pressure cells to Hawaii. The Hawaiian area was inspected on the daily Northern Hemisphere surface charts and the maps were classified for a 25-year period. The two main categories of their classification scheme were described as "anticyclonic" and "cyclonic." The former placed a high pressure cell NW or NE of Hawaii giving surface winds over the islands NE or ESE. The cyclonic situations were characterized primarily by westerly surface winds

[3] California Institute of Technology–Army Air Force.

over the islands with a low center to the NW, N, or NE. Their "anticyclonic" situations are clearly the normal or trade wind weather. They showed that the frequency of the two types varied inversely: the cyclonic was greatest in the December–February period while the anticyclonic was greatest in summer.

Because winter is usually the rainiest season and also the one when cyclonic storms are most frequent, Wallen and Yeh had expected to find a correlation between a yearly precipitation index for Hawaii and the frequency of cyclonic situations for the same year. This correlation, however, was not revealed by their data. They concluded that variations in trade wind rainfall are sufficiently important to mask any direct relation of total rain to the frequency of cyclonic storm types.

The importance of local convective clouds has generally been overlooked in view of the obvious importance of trade wind orographic rain. Leopold (1948) analyzed the time of day of rainfall occurrences on Oahu and Lanai and showed that the leeward or drier portions of these islands receive, primarily, afternoon rainfall. Stations on coasts exposed to the trade winds and those directly in the lee of the mountains receive nighttime rain predominantly, a characteristic of orographic rain in Hawaii (Loveridge, 1924; Jones, 1938). The afternoon maximum was interpreted as resulting from local convective clouds which build up over the drier areas with daytime heating of the ground surface.

Another characteristic type of rain in Hawaii is that of the "naulu storm" (Leopold, 1948), a summertime cumulus congestus or possibly cumulonimbus, which may produce short-duration, high-intensity rainfalls over leeward or dry portions of the islands. The naulu rains result from local convergence where the sea breeze meets the trade wind.

PROBLEMS AND TECHNIQUES IN ANALYSIS

In the analysis of map types, a difficulty which occurs in low latitudes is that the historic series of weather maps does not give sufficient detail on the various low latitude disturbances which have been defined in recent years.

Riehl's studies in Puerto Rico (1945) can be applied with profit to synoptic analysis in the Hawaiian area. An important tool used by Riehl and others for synoptic analysis in these latitudes is a time cross section of winds plotted to the maximum observed height. Pressure and temperature data are also plotted at standard levels. Slight changes in winds, pressures, and temperatures will often show the passage at high levels of minor troughs which may go undiscovered or be poorly defined on the weather maps.

Using a similar type of chart, Stidd (MS.) noticed that in the winter months no rain fell in the drier localities of Hawaii as long as the trade winds were present in the lowest 2,000 or 3,000 feet. Each occurrence of rain was preceded by an almost total disappearance of the trade wind. A positive correlation between rainfall and surface pressure tendencies was also demonstrated, the rainfall occurring in conjunction with rising pressures. Situations in which the axis of the nearest high pressure cell was passing to the east of the station as it sloped toward the equator with height were more productive of rain than those situations in which the axis was passing to the west. This is in accord with general knowledge of the distribution of convergence and divergence about the high cell.

Another aid to synoptic analysis made use of the vast number of weather reports from airplanes flying Pacific routes (Stidd, 1948). This is essentially a graph of time versus distance along a given route, the plane reports being spotted in their appropriate positions. Points of minimum "delta value" (true altitude minus pressure altitude) were found to lie on nearly straight lines in the summertime. The positions of these lines were found to correspond to the positions of easterly waves and the slopes of the lines were a function of the speed of such waves. The full use of all pilots' reports is a time-consuming operation, however, and a thorough test of this method has not yet been made.

Mordy and Leopold (MS.) found highly significant correlation between trade wind rainfall on Oahu and the temperature at 300 mb. (about 30,000 feet msl.) on the Honolulu sounding. This is particularly interesting because trade wind rain falls from clouds whose tops ordinarily do not exceed 10,000 feet msl. Recent studies by the authors indicate that the 300 mb. chart is probably the most important tool in forecasting rainfall in the Hawaiian area.

GEOGRAPHIC DISTRIBUTION OF RAINFALL

Mean annual rainfall maps for the various islands in the Hawaiian group, which improve on the Oahu annual map of Voorhees (1928), are available in the Territorial Planning Board Report (1939). The only monthly isohyetal maps available are median rainfall maps for Oahu prepared by Halstead and Leopold (1948), based on an 11-year period, 1936–1946.

Tüllman (1936), in a study of rainfall distribution over the central and western Pacific, prepared mean annual rainfall maps for the Hawaiian islands of Kauai, Oahu, Maui, and Hawaii. His monthly and annual means were generally based on the 20-year period from 1905 to 1924. The records of those stations which did not coincide with that base period were adjusted. His data came from the published records in *Climatological Data.* Tüllman did the work in Germany and apparently did not have access to Voorhees' map.

Tüllman's isohyetal maps are sketchy, but his graphs of the annual march of rainfall at various stations are of interest. The mean rainfall for each month was plotted on a time-versus-precipitation graph for each station having the requisite records for direct use or adjustment to the 20-year base.

The Weather Bureau, in the publication *Climatological Data,* groups the stations of each island in geographic units selected primarily to divide windward from leeward stations. Oahu, for example, is divided into six areas. Using the stations within each of these geographic units, Tüllman compared qualitatively the curves showing the annual march of rainfall at each station and grouped together the stations which had similar curves. This provided two or three groups within each geographic unit. Those stations lying in the same elevation zone had similar annual march curves.

It was unfortunate that Tüllman did not discard the arbitary geographic units of the Weather Bureau and lump all stations having similar annual march curves. He would thus have been able to delineate, on various islands, zones which are similar in distribution of rainfall during the year. This would be one indication of similarity in rainfall processes. In a single given month there are large differences between the mean rainfall for each island; moreover, during a given storm, geographic units having apparently similar exposure may record widely different rainfall amounts. The problem of determining areas of similar rainfall processes is, therefore, not as simple as might be expected. Delineation of such areas is important in the problem of developing techniques for both short- and longer-term quantitative rainfall forecasts for various portions of each island.

Tüllman's group curves can be analyzed and consolidated to provide the recapitulation mentioned. Only moderate accuracy could be expected, however, because he did not publish the numerical rainfall data in tabular form with the curves. Quantities could be determined only as accurately as the small-scale curves could be read.

The most striking features of the annual march curves are the exceptionally low mean rainfalls for certain months. All groups of stations for Kauai show a low rainfall in February, as low as, and in some cases lower than, the mean for June. Yet January and March tend to be among the months of highest rainfall. This depression in February means is apparent to a lesser extent in all curves for Oahu, in those for the northeast slopes of west and east Maui, and for the northeast coast of Hawaii.

Radical increase in rainfall in November over October appears on the northeast coast of Ha-

waii at all elevations, and in the high rainfall zone of east Maui at elevations of 3,000–4,000 feet.

The northeast exposures of both east and west Maui and the high rainfall zone of eastern Hawaii show marked rainfall minima in June, October, and February. The same zones generally show sharp maxima in August, December, and April. Yet leeward Hawaii and Maui, all of Oahu, and all of Kauai exhibit no such striking behavior.

The 20-year period on which Tüllman based his mean rainfalls is sufficiently long to be considered fairly representative. The curves for certain of his groups might not have contained enough stations of long record and thus the adjustment procedure may have significantly affected their representativeness. Yet the consistency of these variations between certain areas lends credence to them.

An unpublished study by the authors (Stidd and Leopold, MS.), using more recent data, reaches conclusions which are in agreement with Tüllman's findings. This study discusses two individual components of Hawaiian rainfall and shows that their annual cycles are quite different. The cycle of cyclonic activity is shown to have a winter maximum and a summer minimum while the cycle of orographic activity is found to have a three-phase annual cycle with minima in June, October, and February. These minima correspond exactly to the minima of rainfall found by Tüllman in the very wet regions of Maui and Hawaii.

The study also shows that mean monthly rainfall distributions have the same type of pattern as the mean annual distributions, the only fundamental differences being in spacing and values of the isohyets. A quantitative statement of these two variables is shown to define adequately the rainfall distribution and magnitude for any mean month.

The study implies that the pattern of mean annual rainfall can, as an approximation, serve as the pattern for rainfall over any given period of time, and quantitative daily forecasts of rainfall based on this approximation are now being made.

Because of the skewness of the frequency distribution of monthly rainfall values, the arithmetic mean is a poor statistic to represent normal values of Hawaiian data. The occurrence of abnormally wet months causes the mean rainfall values to be significantly greater than median values. Landsberg (MS.) showed that median monthly rainfall values for Hawaiian stations reach stability in a shorter period of record than do means. But he noted that for an island as a whole, "the pattern of ishoyetal maps . . . if medians are used, shows no material difference in areal distribution compared to maps using mean-value isohyets. The difference is one of absolute values, not a shift in the location of drier or wetter areas."

The greatest monthly and annual values of precipitation are obviously in the mountain area. Annual means vary from 450 inches on Mount Waialeale to less than 10 inches on the lee side of Maui. Studying the Honolulu area, Voorhees (1928) found the correlation coefficient between mean annual rainfall values and station elevation to be only +.21; correlating annual mean with distance from the mountain crest gave a value of —.81. The maximum rainfall area in the Koolau Range on Oahu, average elevation 2,000 feet, lies about a mile leeward of the mountain crestline. The Koolau Range is long and narrow and is oriented perpendicularly to the trade wind.

The essentially conical-shaped mountain ranges of central Kauai and west Maui reach maximum elevations of about 5,000 feet. In both instances the maximum rainfall zones coincide with the maximum elevations. Yet on the higher (10,000–14,000-foot) conical mountains of Haleakala (east Maui), and of Mauna Loa and Mauna Kea (Hawaii), the zone of greatest annual rainfall is on the windward side at elevations of about 3,000 feet, a fact noted by both the Territorial Planning Board Report (1939) and Jones (1942). Leopold (MS.) attributes

the different elevations of maximum rainfall to convergence resulting from horizontal splitting of the trade wind by the higher mountains.

It is stated in the Planning Board Report (1939) that only in the Kona area (western portion of Hawaii) does the summer rainfall (May to October) exceed that of winter. However, Tüllman's curves, checked by current investigations of the authors, have disclosed that some of the wetter areas on Oahu and Hawaii have summertime maxima.

Correlations between the wind direction aloft (10,000 feet) and the geographic distribution of rainfall were made by Wallen and Yeh (MS.). Though their conclusions are tentative, they indicated that relative to the direction of wind at 10,000 feet the rainfall maxima appeared on the lee side of islands and the minima on the windward sides. Though this at first seems contrary to the expected orographic effects, Wallen and Yeh present a qualitative picture of distribution of convergence and divergence which might explain the observed rainfall pattern.

Riehl (MS.) studied 10 years of daily rainfall records at 21 rain gages in north central Oahu. He delineated four districts which approximately coincide with the areas known locally as Waimea, Waialua, Wahiawa, and Helemano. At the outset he defined "effective" precipitation as rain of 0.10 inches in a day at a given station. In summer 20 per cent of the total rainfall occurs in showers of less than 0.10 inches in a day and is, therefore, ineffective. In winter only a negligible amount is ineffective. Of the total *number of days* of rain, 40 per cent in winter and 60 per cent in summer are ineffective. For the remainder of his study, only "effective" rain was considered. He then defined a "rainstorm" as one which "in each of the four districts half or more than half of the stations received [effective] precipitation." He concluded that 80 to 90 per cent of the total precipitation occurs in "rainstorms."

Isohyetal patterns of mean monthly rainfall due to "rainstorms" show higher rainfall over the mountains than over the plains. In other words, orographic lifting is an important factor determining rainfall distribution in general storms.

Riehl found that rainstorm precipitation is more evenly distributed from mountain to plain in summer than in winter.

MONTHLY AND ANNUAL VARIATIONS IN RAINFALL

Variations in yearly values of rainfall for Oahu stations were studied by Nakamura (1933). As an index of this factor he computed the ratio of standard deviation to mean annual rainfall for each of certain stations. Isopleths of this index showed that the smallest year-to-year variation occurred in the high rainfall zones of the mountains and the largest variations in the leeward, drier areas.

Landsberg (MS.) found that for 11 Oahu stations, every month of the year had had, in one individual year or another, the smallest monthly rainfall total in the year. As a measure of the skewness or asymmetry of the monthly rainfall frequency distributions he computed the value $\frac{\text{median-mean}}{\text{mean}}$ for each of the 12 months, at a given station. By averaging the ratios for the 12 months, each station would be represented by an index of asymmetry. These values for each of 22 Oahu stations plotted on a map showed that the greatest asymmetry occurred in lower leeward stations, and the least in windward and mountain stations. This is similar to the coefficient of variation computed by Nakamura and described above, and it checks his geographic distribution.

Another indication of the smaller variations in rainfall at higher stations is provided by Wentworth (1946), who studied the interstation correlation of amounts of annual rainfall on Oahu. Annual rainfall values at various pairs of stations were expressed as ratios, year by year. Wentworth computed the mean ratio between pairs of stations as part of an analysis of the frequency distribution of these ratios.

The best correlated pairs of stations had a probable deviation from their mean ratio of less than 10 per cent. For those pairs having poorest correlation, the most probable deviation in a single year was 45 per cent. The best correlated pairs were found among the high rainfall stations, while the low rainfall stations showed the greatest deviations.

Wentworth's study is important also to students of hydrology. He showed how the interstation correlations could be used to synthesize missing annual rainfall amounts at stations whose records are sufficiently long to establish the initial correlation. The method provides indices of reliability for such interpolated records and could be used on monthly as well as annual values.

Riehl (MS.) found a double maximum of effective precipitation in both summer and winter, as had Landsberg (MS.) and Tüllman (1936). Riehl attributes the minima in June and September to the seasonal shift of the subtropical ridgeline in the high troposphere. This ridge is centered over the latitude of Hawaii in June and September, having moved north in midsummer and southward again in the fall.

Secondary maxima of rainfall in winter are not due to a change in the number of storms, of which there is a single maximum in winter. Riehl concludes that at the beginning and end of the winter season there is the greatest possibility of interaction of summer-type tropical disturbances with the extra-tropical winter storms. This leads to the double maximum of rainfall in winter.

Riehl finds that 80 to 90 per cent of the total rain occurs in the general storms or "rainstorms." From this he concludes that present forecasting techniques which should allow the forecasting of these storms are sufficient to solve the main problems of agricultural forecasting for Hawaii.

The cyclic behavior of rainfall has been studied by a number of workers. Cox (1924) constructed an index of monthly rainfall values based on 10 stations and extending over 44 years. He concludes that a cycle of 3.7 years appears to exist and is even stronger than the annual cycle.

Johnson (1946) analyzed yearly rainfall amounts at one station, Kualapuu, Molokai, by the method proposed by Alter (1937). Wentworth (1947) in reviewing this work concisely describes the method as "a process of finding that constant interval between pairs of years such that the average difference in rainfall between the two members of a pair is a minimum."

At Kualapuu, the 20-year periodicity was the strongest, and the 12-year cycle was second strongest. For the Honolulu record, a 14-year cycle appeared most probable with the exception of cycles of 36 years and certain others too close to the length of the 66-year record to be very reliable. Using the "Honolulu Rainfall Index" (the average of the percentages of the annual mean for 10 stations in the Honolulu area), Wentworth (1947) applied Alter's method to find the most probable cycles in the annual values of this series. He showed that the 16- and 20-year cycles were the most promising.

Working with the monthly values of rainfall at Waimanalo, Landsberg (MS.) showed by harmonic analysis that the annual variation is a wave which is not accidental. He decided that the existence of other periodicities in the data for that station was not probable.

The fact that the lengths of most probable cycles differ among stations or groups of stations in the islands markedly reduces the usefulness of, if not the confidence in, such cycles. Wentworth's analysis was the most practical. He showed that the average deviation of the "predicted" rainfall index from the actual can be reduced by using the 20- and the 12-year cycles. In individual years, however, the difference between actual value and the mean value was less than that between the actual and the value predicted by use of the cycles. Wentworth concludes, therefore, that "for practical purposes, any statistical, long-run gain is canceled by the evident risk of an aberrant estimate for a given year."

If, on the other hand, it can be shown that for certain specific purposes a reduction in average error of estimate outweighs the importance of very large errors in estimate for individual years, application of the technique should be considered.

The work of Solot (1948) has opened up new fields for the growth of longer-range forecasts for Hawaii. Having classified individual months on the basis of average rainfall for the Territory of Hawaii and on the average number of days of rain, he segregated monthly mean surface pressure maps for the Pacific area. The anomalies of mean pressure for individual months from the long-time average pattern were distinctly different for wet and dry months. Wet months are characterized by higher than normal pressure in the Aleutian area and a weak low in the mean pressure field over Hawaii. Dry months, on the other hand, have abnormally low pressure near the Aleutians and higher than normal pressure over the Hawaiian Islands.

Because there is some month-to-month persistency in the patterns most different from normal, these pressure anomaly patterns have some forecast value. Solot found that near-normal pressure distributions apparently have no significant persistence and the forecast value is dubious.

This distribution of anomalies fits the general knowledge of Hawaiian rainfall. Wet months, at least in winter, are characterized by a dislocation of the Pacific high and the admittance of cyclones to more southerly paths.

Riehl (MS.) interprets the import of Solot's correlations of pressure patterns and rainfall as follows: Mean monthly pressure patterns do not indicate deviations from average conditions which "would tend to raise or suppress rainfall throughout the month. They denote a basic state of the general circulation favorable or unfavorable for generation of a few potent disturbances."

Another possible forecast tool is provided by the work of Yeh (MS.). He found that there is some general relation between the latitude of the belt of maximum west wind at 10,000 feet (the jet stream of Rossby) and precipitation in Hawaii. When the jet stream lies south of 40° N. Lat. on a given day, the probability of rainfall over Hawaii is small. Positions between 50° and 60° N. apparently are associated with higher rainfall probability.

WINDS

Most of the older studies of upper air data over the Pacific are of little significance in the development of forecast techniques. Beals (1927*b*) presented wind roses for various levels above Pearl Harbor, later extended to higher levels by Thomson (1928). The latter showed that the west winds, which surmount the low-level trade wind easterlies, reach lowest elevations in March and April on the average, while the height of the easterlies is greatest in May and June.

Beals (1927*a*) showed that the surface wind at Honolulu progressively changed in mean direction from northeasterly to a more easterly flow between 1905 and 1924. Wentworth (1949) has brought this study up to date and finds that in the last decade the earlier trend has been reversed, the mean winds gradually backing to a more northeasterly direction.

The diurnal patterns of wind have been discussed by Beals (1927*a*), Henry (1925), and Leopold (1948). In summary, sea and land breeze regimes control the wind direction in the lowest levels on the protected coasts of all the islands.

Leopold (1948) noted that the line along which the sea breeze meets the trade wind is associated with the development of a cloud line on Lanai, Molokai, and northeastern Hawaii. Diurnal changes in cloudiness in many areas are related to the development of sea and land winds. The regime is particularly apparent along the Hamakua (northeast) coast of Hawaii where drainage winds from Mauna Kea keep the slope clear at night; during the day the sea breeze reinforces the trades and causes an afternoon maximum of cloudiness.

At Honolulu and on the easterly coast of Oahu the surface wind is normally easterly at all hours with a maximum speed in the afternoon and a nocturnal minimum. Leopold (1948) relates this to surface stability at night. He showed that at Honolulu winds between 1,000 and 2,000 feet have a maximum speed at night. This, apparently, is caused by horizontal convergence as the subsidence temperature inversion reaches its minimum height at night.

CLIMATE IN RELATION TO CROPS AND VEGETATION

Maps of the areas covered by different vegetal associations have been compiled by Ripperton and Hosaka (1942).

There is evidence of change in vegetation in certain areas, the most prominent being noted in the Waimea area of Hawaii where many square miles formerly in heavy forest now constitute a grassland containing large amounts of an introduced cactus. A local wind storm, known as "mumuku," is said to have decreased markedly in frequency between 1830 and 1856. The change was attributed to the introduction of cattle and subsequent modification in vegetation (Anonymous, 1856 and 1926).

In a series of papers, Das (1928, 1931 *a,b*) analyzed the relation of monthly sequences of temperature and rainfall to the production and quality of sugar. High-quality cane juice was apparently correlated with high temperatures during the first summer after planting and with cooler weather in the winter prior to harvest. Rainfall should be relatively low during the winter season and relatively high during the summer to produce the best quality of cane. Das found that a wet August in the summer prior to harvest was strongly correlated with high yield.

BASIC DATA

Few areas of comparable size have the large number of rain measurements made in Hawaii. Approximately 900 rain gages, most of which are kept by sugar and pineapple plantations and by cattle ranches, are currently installed. About three-fourths of these gages are read daily. The data from 205 are published as daily values in *Climatological Data*; in addition there are 79 stations for which monthly values only are published. A survey of basic rainfall data being collected currently has been made by Leopold, Burn, and Stidd (1948).

Surface wind observations are few except on the island of Oahu and the only upper wind data are collected by the Weather Bureau from Honolulu.

For studies of phenomena of the lowest 4,000 feet of the atmosphere, the location of the Honolulu Airport from which the Weather Bureau radiosondes are flown is poor. With respect to the trade winds the office is about 8 miles leeward of the Koolau Range, whose peaks in this vicinity reach 3,000 feet.

Forecasting at Honolulu is very dependent on reliable and continuous upper air observations at the existing ship stations and on Midway and Johnston Islands. Full use of pilot reports, particularly in summer, will probably become more essential as improved techniques develop.

DIRECTION OF FUTURE WORK

The strong geographic patterns of rainfall totals should make the development of a scheme for quantitative short-range rainfall forecasts relatively simpler than in many other places. On the other hand, significant differences between apparently similar areas on different islands loom large as potential difficulties. Four directions of work are necessary: (1) the definition of criteria for expressing the strength of pressure troughs locally affecting the Hawaiian Islands; (2) the correlation of these criteria with rainfall quantities; (3) inter-correlation of rainfall between different stations or localities; and (4) an improved understanding of the structure of the high troposphere and lower stratosphere.

To attain these ends certain groundwork is required. In connection with quantitative measures of the importance of various upper air

factors influencing rainfall, a series of well-analyzed upper air charts together with time–height sections of wind and radiosonde data must be collected. Past maps available at the Honolulu Weather Bureau office only partially fit this need. After teletype sequence data are destroyed, plotting of the necessary time–height sections is made difficult.

Correlation of rainfall values with the upper air data and inter-station correlation require better organization of the basic rainfall data. In January, 1948, a scheme for routine collection of all rainfall quantities in a centralized location was initiated by the Pineapple Research Institute and the Hawaiian Sugar Planters' Association Experiment Station.

The attainment of longer range forecasting techniques is apparently in sight as a result of Solot's work and that of the Extended Range Forecast Section of the U. S. Weather Bureau. For the best use of such forecasts the same problems of inter-station correlation are met, this time with monthly rainfall values. Month-ahead rainfall forecasts made by the Weather Bureau for Hawaii are now being tested by selected sugar and pineapple plantations.

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The Status of Native Land Birds on Molokai, Hawaiian Islands

FRANK RICHARDSON[1]

MOLOKAI, the fifth largest of the Hawaiian Islands, is 38 miles long and about 10 miles wide. Its eastern half is high land running up to almost 5,000 feet in height. Some rather extensive areas of native forest still remain on the upper slopes, but introduced plants have displaced the native growth over large areas. In spite of the large area and the amount of cover, the rather intensive observations of the Hawaiian Bird Survey from 1935 to 1937 resulted in only a single record (Munro, 1944: 96) of a native land species on Molokai—the apapane (*Himatione sanguinea*). The survey covered large areas of native forest, chiefly in the east–central part of the island, where endemic birds had once been abundant. Munro thought he heard the song of the Molokai thrush (*Phaeornis obscura rutha*) in 1936 but was not certain. Richards (1946: 29) probably saw amakihis (*Chlorodrepanis virens wilsoni*), but this too is uncertain. Bryan (1908) was apparently the last ornithologist to observe and collect various native birds that have since become extinct or nearly extinct. He saw Perkins' mamo (*Drepanis funerea*), the crested honeyeater (*Palmeria dolei*), the Molokai creeper (*Paroreomyza maculata flammea*), and other native birds. Certain species, such as the ou (*Psittacirostra psittacea*) and the oo (*Acrulocercus bishopi*), were almost certainly extinct even then.

The survey of 1935–1937 appeared to indicate that nearly all native birds formerly found on Molokai were extinct. However, the survey did not cover certain parts of the island, especially isolated canyons and highlands on the northeast side. Consequently, David Woodside and I undertook a visit to this little-frequented region. Our chief purpose was to observe birds on Olokui Mountain, which towers over 4,600 feet above and east of Pelekunu Valley which was a favorite collecting area of the fabulously successful collectors of the late nineteenth century. Bryan, as far as we could determine, was the only ornithologist who had been up on Olokui, and he probably covered only a small part of it. We hoped that the mountain, because of its great encircling cliffs and the bordering, deeply cut Pelekunu and Wailau Valleys, had escaped most human influences and that native birds which had long since disappeared from other parts of Molokai might have survived there. Munro, who is more familiar than anyone else with Molokai birds, repeatedly mentions (1944) Olokui as the last possible refuge for endemic birds on Molokai.

Mr. Woodside and I, with Harold St. John and two botanical assistants, landed at the mouth of Wailau Valley on February 2, 1948. The next day we followed the seaward ridge of Olokui (Fig. 1), and ascended the mountain to a height of about 3,000 feet, cutting our way through the thick plant growth above approximately 1,500 feet. We established a base camp at 3,000 feet, and during the next 3 days made trips into the canyons on the east side of Olokui to within half a mile of its top. After descending the mountain we crossed the island by hiking up Wailau Valley, climbed the steep south wall to its 3,000-foot rim, and then made the more gradual descent to Mapulehu.

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We saw only two species of native birds on Olokui — the apapane and the amakihi — but their abundance was noteworthy. Although we covered probably less than 3 linear miles, we saw well over 100 apapanes. A few of these were very likely "repeats," but pairing and territories, which would have led to seeing the same birds along the same route, were not detected. Groups of as many as five apapanes were seen. Some disappeared over Wailau Valley and others appeared to be flying to Olokui, which suggested the likely abundance of this species in the high native forest to the east of Wailau. Only five, or possibly eight, amakihis were seen, but all were found in the same region near the lower edge of the native forest. Individuals were seen here on both our ascent and descent of the mountain, which suggested a reasonable abundance of this species even though it is apparently restricted in range. One amakihi was collected for certain identification. It is interesting that Bryan (1908: 158, 162) considered the apapane the most numerous species in 1907 and the amakihi the second most numerous.

St. John considers the forest of Olokui as perhaps the finest unaltered native stand he has seen in the islands. The accompanying photographs (Figs. 1–4) record typical views of this forest. Several species of lobelia and the ohia lehua *(Metrosideros collina)*, the dominant tree, were blooming. The olapa *(Cheirodendron Gaudichaudii)* was another abundant tree species. However undisturbed the native forest may appear, and however suitable it may seem for several species of native birds other than those observed, it is certain that the vertebrate fauna has been greatly disturbed, presumably by introduced vertebrates. Two non-native bird species were present: the white-eye *(Zosterops palpebrosus japonicus)*, in an abundance probably only slightly less than that of the apapane, and the Chinese thrush *(Trochalopterum canorum)*, heard twice but seen only once. It appears that the apapane and amakihi have estab-

FIG. 1. View down northeast ridge of Olokui Mountain to mouth of Wailau Canyon. Trees in foreground are chiefly ohia lehua (*Metrosideros collina*) with light-colored kukui (*Aleurites moluccana*) interspersed below.

lished a balance with these alien species, but the possible effects of the non-native forms on species not now extant can only be conjectured.

Non-native mammals may well have altered the ornithological picture considerably. One mongoose (*Herpestes griseus*) was seen far up on Olokui, suggesting that the species, which is difficult to see in dense forest, is probably common. One rat seen high in a tree was collected and identified as *Rattus rattus alexandrinus*. Others had been eating the bananas of a small cluster of plants hidden in the native forest. Even in 1907 Bryan found evidence that the mongoose was decimating the population of the ground-nesting dark-rumped petrel (*Pterodroma phaeopygia sandwichensis*). The rat may also be a serious enemy of ground-nesting birds and of many tree-nesting forms as well, since it is a good climber. Pellets of the Hawaiian owl (*Asio flammeus sandwichensis*) made up of rat remains were found at and below the lower edge of the native forest. This native predatory bird, which has been known in recent years from unforested parts of Molokai, could rarely if ever obtain rats in the dense native growth of most of the mountain. Goats, although abundant on the lower open canyon sides, have penetrated the native forest less than one-fourth of a mile. Undergrowth, especially of the uluhe fern (*Dicranopteris linearis*), seems to hinder their further ingress. The goat seen highest on the mountain was immediately below ohia lehua trees where we first observed apapanes and amakihis. Goats had not yet markedly altered the native trees at this elevation, although the lower vegetation was much changed.

Various native birds (white-tailed tropic bird, black-crowned night heron, wandering tattler, and golden plover) were seen in Wailau Valley, but no endemic passerines were observed. Introduced birds seen were the Chinese dove, the mynah, and the white-eye. Little native vegetation remains in the lower part of the canyon but good stands of native growth were encountered on the steep south wall. Apapanes and amakihis were again seen here as

FIG. 2. Forest on Olokui Mountain. Large-leaved tree at left is alani (*Pelea clusiaefolia*). Fern in foreground is okupukupu (*Nephrolepis exaltata*). Dr. Harold St. John in foreground.

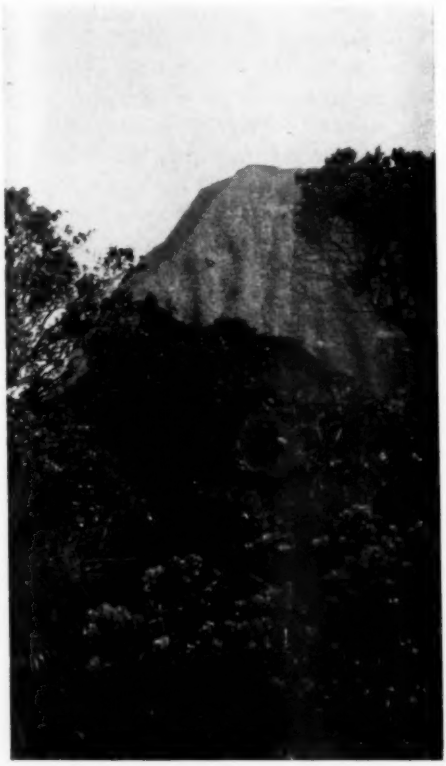

FIG. 3. Ohia lehua forest on Olokui looking across to east wall of Wailau Valley.

were white-eyes and a Pekin nightingale (*Leiothrix lutea*).

Even on Olokui our observations were not extensive enough to rule out the possibility of the existence of other native forest birds. The restricted area of rather uniform native habitat makes it seem likely that such birds, if they do exist, are very rare. However, the probably smaller number of individuals of tropical species and their not infrequently vagrant habits would necessitate a longer stay than ours before a reasonably sound conclusion could be reached. Woodside was almost certain he heard the song of an iiwi (*Vesteria coccinea*) from the south wall of Wailau Valley, so this species should be sought with particular care in the future.

A striking change was evident in the vegetation on the south rim of Wailau Valley. The southeastern half of Molokai slopes relatively uniformly and not very steeply to the south. Remnants of native forest cover some of the higher areas and it was chiefly here that the Hawaiian Bird Survey was conducted. However, on the broad slopes down to Mapulehu and on large areas on each side of our route, the native forest has virtually disappeared. Dead or scraggly ohia lehua trees represent what was apparently the dominant forest. Grasses have taken over much of the now-open slopes.

No sign of native birds was seen during our descent from the rim of Wailau, and undoubt-

FIG. 4. Ohia lehua on Olokui. Fern at lower left is uluhe (*Dicranopteris linearis*). David Woodside in tree.

edly none was to be expected under such changed conditions. Bordering canyons appeared to have relatively unchanged native cover, and certain rather extensive high forested areas exist in the Kahanui region. As indicated by the absence of native birds on the Survey, much of the eastern half of Molokai seems to be so cut up by areas of altered forest conditions that such birds have disappeared.

Our cursory inspection of southeastern slopes of Molokai does not justify detailed analysis of the factors which have caused major forest changes. It seems clear, however, that the large introduced vertebrates have been the primary cause. Deer, cattle, and pigs range or have grazed over much of the region. Although they are most likely to occur in more open areas, the deer and cattle have penetrated the deep boggy type of native forest and also the less dense ohia lehua forest where the slopes have not been too steep.

Our observations on Molokai indicate that the remaining native forest birds are rather closely restricted to the northeast parts of the island where unaltered forest areas are most extensive and continuous. Olokui Mountain and the sides of Pelekunu and Wailau Valleys probably include the major part of the range of these native birds. In these regions there has been little or no penetration by large introduced mammals. It seems likely that the continued welfare of the remaining native birds rests in fair measure on not introducing these mammals into the parts of Molokai which they have not invaded. Pigs, deer, and cattle apparently do not now occur in Pelekunu and Wailau Valleys, but once in these valleys it seems apparent that they would work their way up the least precipitous slopes and irreparably alter the native forest.

Acknowledgment is made to the Division of Hydrography and to the Division of Fish and Game of the Territory of Hawaii, to the University of Hawaii, to the Hawaiian Sugar Planters' Association, and to the United States Army for their cooperation in making possible this trip to a very inaccessible region. The photographs were taken by Robert St. John.

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A Taxonomic Revision of the Genus *Neraudia* (Urticaceae)

RICHARD S. COWAN[1]

INTRODUCTION

THE GENUS *Neraudia* is in the family Urticaceae and is endemic to the Hawaiian Islands. It is found from about 1,600 to 4,000 feet altitude but is seldom represented by more than a few plants in any locality. The lack of a large volume of material, the difficulty of collecting plants of the genus (both conditions resulting from its rarity), and some nomenclatorial confusion have contributed to the lack of understanding of the group. Even now, after the collections and observations of the past 2 years, it is felt that several more years of collection and observation are necessary to furnish sufficient material for evaluating more clearly some of the taxonomic entities included below. Even on the island of Oahu, which has been the most widely explored botanically of any of the Hawaiian Islands, more study of this genus is needed.

Acknowledgments: Dr. Harold St. John, Chairman of the Department of Botany, University of Hawaii, suggested this genus as one in need of study and possible revision. He has directed my work and I wish to express my gratitude for his aid and guidance. I also wish to acknowledge the kindness of Marie C. Neal, Curator of the Bernice P. Bishop Museum Herbarium (Ho[2]), inasmuch as the following work could not have been accomplished had it not been for the material borrowed from the herbarium. I am likewise grateful to Otto Degener of Honolulu for the loan of his collection of this genus. To the Royal Botanical Garden, Kew, England (K); the Herbarium of the University of California (UC); Gray Herbarium, Harvard University (GH); New York Botanical Garden (NY); Museum National d'Histoire Naturelle de Paris (P); Conservatoire et Jardin Botanique, Geneva (G), I wish to express my appreciation for the loan of material of earlier collectors. Finally, to the friends and associates, particularly K. Sakimura of the Pineapple Research Institute of Hawaii, who have searched and collected as intently as I, I express my gratitude. I am particularly indebted to Florence (Mekeel) Lambeth for making the fine drawings for this paper. Her keen sense of proportion and attention to detail, her unreserved spirit of cooperation, and her ability to make herbarium specimens appear as fresh material have been an important contribution.

HISTORY OF THE GENUS

The genus *Neraudia* was published by Gaudichaud on March 6, 1830, in the botanical account of his first trip around the world on the "Uranie." He named the genus in honor of M. Néraud, a French lawyer and amateur botanist of Madagascar with whom he became acquainted during his visit to that island. Gaudichaud described and illustrated *Neraudia melastomaefolia* and described *Neraudia ovata* on the basis of material which he collected in the "Sandwich Islands." In 1851 he published a plate illustrating a third species, *Neraudia sericea,* without description, the material for the plate having been collected by Gaudichaud on his second trip, this time on the "La Bonite" voyage. The plate, in

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[2] The standard symbols proposed by J. Lanjouw (1939–1941) for each herbarium are shown after the name of each institution and these are used in the lists of collections examined to indicate where each collection is deposited.

spite of being rather diagrammatic and lacking accuracy in some details, must nevertheless be accepted as valid publication since it is a "plate with analyses," which, according to the International Rules of Botanical Nomenclature, constitutes valid publication prior to 1908 (Art. 44). In his Généralities, published in 1827 and occupying the first part of the volume on the botany of the voyage of the "Uranie," he mentioned three specific epithets. The first, *melastomaefolia,* he retained when he published the genus in 1830, but the second, *pyrifolia,* he evidently changed in favor of the third, *ovata,* before he published the description.

Meyen (1834–1835), in the section of his journal concerning his experiences in the Sandwich Islands, described several new species, one of which was supposedly a new species of *Neraudia, N. glabra.* He wrote that the natives called *N. melastomaefolia* "mamaku," which is essentially "mamake," the name now applied to *Pipturus* spp. In his original description and again in 1843, when he transferred his species to the genus *Boehmeria,* Meyen described the leaf margins as crenate. This is particularly significant in that there are no collections of *Neraudia* which show such leaf margins and it is very likely that Meyen did not have a *Neraudia.* For this reason, the name is here excluded (see discussion accompanying *N. melastomaefolia* var. *parvifolia* for more complete explanation). Hooker and Arnott, who studied the plants brought back from the Beechey Voyage, in 1832 transferred the two known species of *Neraudia* to the genus *Boehmeria,* pointing out that in their opinion the two genera were indistinguishable.

Endlicher in 1837 and Steudel in 1841 transferred the described species to *Boehmeria.* Weddell, however, in 1856 accepted the genus and recognized *N. melastomaefolia* and *N. sericea,* giving the latter its first description. *Neraudia ovata* he reduced to β-variety of *N. melastomaefolia.*

Wawra in 1874 accepted *N. melastomaefolia* and *N. sericea* without mention of *N. ovata.* He described a forma *parvifolia* of *N. sericea* with a question mark. The question mark would seem to indicate either that he was not sure what *N. sericea* was or that he was not sure what rank his entity should have. It seems that he did not know to what the name *N. sericea,* should be applied as he used it for a group occurring on Kauai *(N. kauaiensis).* The form which he described was later recognized by Hillebrand with a change of status and it is herein accepted. Word has recently been received from the director of the herbarium at Vienna, where Wawra's and Meyen's material was preserved, that the section of the herbarium including the Urticaceae was destroyed by fire during the recent war, so it is unlikely that their material will ever be available for study. Furthermore, in 1935 neither St. John nor the director of the herbarium was able to find the specimen which Wawra had used as a basis for his forma *parvifolia.*

Bentham and Hooker in 1880 accepted the genus and remarked simply that two or three groups occurred in the Sandwich Islands.

Hillebrand in 1888 accepted Gaudichaud's *N. melastomaefolia* listing *N. ovata, N. glabra, Boehmeria melastomaefolia,* and *B. glabra* as synonyms. The name *Neraudia sericea,* he used incorrectly, applying it to a variety of *N. melastomaefolia.* He then described a new variety of *N. melastomaefolia,* var. *Kauaiensis,* and transferred Wawra's forma *parvifolia* of *N. sericea* to *N. melastomaefolia,* raising it to varietal status. On the basis of a scrap of material collected by John Lydgate on the island of Kahoolawe, and of which no one has seen material since, he described a new species, *Neraudia Kahoolawensis.* Engler in 1893 accepted the genus noting "2–3 Arten auf den Sandwich-Inseln."

In 1944 Skottsberg described forma *truncata* of *N. melastomaefolia* based on *Selling 3363* from the Waianae Range of Oahu. This name is treated here as a synonym of *N. melastomaefolia* var. *parvifolia.*

In the taxonomic portion of this paper I have attempted to discover what the older concepts were and how the names were applied by studying available plates, descriptions, and the types of some of the groups.

RELATIONSHIPS OF THE GENUS NERAUDIA

Taxonomists differ in their interpretation of the family Urticaceae but even if it is divided into four families, as is done by many workers, *Neraudia* is still most logically assigned to the segregate family Urticaceae. As may be seen in Table 1, *Neraudia* shows some of the characters which have been used to separate two of these families. To summarize the table: the genus shows two characters overlapping between the two families; three features in common with the Urticaceae; one feature characteristic of the Moraceae. The presence of this overlapping would seem to indicate that the lines separating the families are not particularly well-defined. The use of the milky sap character in the segregation is not worthy of the importance attached to it by some workers. Possibly the aggregate interpretation of the family with several tribes would be a more logical and valid one than that of several rather weakly delimited families.

To determine which genus of the Urticaceae *Neraudia* most closely approaches morphologically (in an attempt to establish relationships) I have made a relatively complete review of the treatment of the family by Weddell (1856–1857). In his key to the genera of the "Boehmerieae," *Neraudia* is placed in a group with *Cypholophus, Sarcochlamys, Touchardia,* and *Laurea.* Of these, *Cypholophus* seems to be the genus most similar to *Neraudia.* In *Cypholophus* a fleshy perigone develops at maturity but it invests the achene very closely, whereas the achenes of *Neraudia* are completely free, with considerable space between them and their perigones. The flowers of *Cypholophus* are borne in dense heads as contrasted to the very loose groups of individual flowers of *Neraudia.* I find that *Neraudia* (in Weddell's treatment) shows the greatest morphological similarity to a genus of the preceding section of the key, the genus *Pouzolsia,* rather than to any of those in the previously mentioned section. This is a large genus distributed throughout the tropics with nine species in the Indian area and three from the East Indies. Table 2 presents some of the similarities and dissimilarities between these two genera. A definite statement of the relationships of these genera cannot be made until material of *Pouzolsia* from the many localities where it occurs has been examined critically; it does seem, however, that there is rather close relationship between the two.

There is also considerable similarity in general habit, floral structure, leaf characters, and type of fruit in *Neraudia, Pipturus,* and *Boehmeria,* but the first is separable from the others by the accrescent, fleshy calyx which surrounds the achene when it is mature. The achenes of *Pipturus,* surrounded by the dried and shriveled calices, are imbedded in a white, insipid, fleshy mass in the leaf axils.

TABLE 1

RELATIONSHIPS OF *Neraudia* TO THE SEGREGATE FAMILIES MORACEAE AND URTICACEAE.

CHARACTER	URTICACEAE	MORACEAE	NERAUDIA
Sap	Watery	Milky	Milky
Phyllotaxy	Alternate or opposite	Alternate	Alternate
Fruit	Achene	Aggregate or multiple	Achene
Stamens	Folded inward	Folded inward or straight	Folded inward
Ovule	Erect	Pendulous	Erect
Embryo	Straight	Curved or spiral	Straight

DISTRIBUTION OF SPECIES AND VARIETIES

Neraudia, which is restricted to the Hawaiian Islands, is represented on most of the major islands—Kauai, Oahu, Maui, Molokai, Lanai, and Hawaii. With only one exception, the groups are restricted to one island or to one particular part of an island. The exception is *N. sericea,* which occurs on Maui, Lanai, and Molokai. The varieties of *N. melastomaefolia* occur on three islands, variety *pubescens* on Kauai, variety *pallida* on Maui, and the other four varieties on Oahu.

In the Waianae Range of Oahu a greater number of groups is found than in any other island locality, for in this region grow varieties *melastomaefolia* and *parvifolia* of *N. melastomaefolia* and both varieties of *N. angulata.* In the Koolau Range of Oahu are found two of the varieties of *N. melastomaefolia—uncinata* and *Gaudichaudii.* An examination of the "total number of groups per island" in Table 3 shows that the number of groups per island decreases progressively to the south and to the north of Oahu. From this observation it is postulated that the island of Oahu received the ancestral form which has given rise to the groups of this genus. Certainly the number of groups on Oahu would indicate a considerable period of active speciation during which time propagules have been transported to most of the other islands with subsequent modification of the introductions.

Altitudinally, members of the genus range from 1,600 to 4,000 feet. They are found in extremely dry to wet situations. Most of the groups are collected in moist regions but *N. ovata* grows in very dry soil or in rough lava fields. *N. sericea* also has been collected (as far as can be determined from scanty data) in the lower xerophytic forests growing in dry soil or in lavic regions.

TAXONOMIC CHARACTERS USED IN CLASSIFICATION

As in the floras of most regions, in the Hawaiian flora are a number of genera the species of which have been shown to evidence extreme variability. Much of the variation in a population is undoubtedly due to genetical differences but a certain proportion must be due to the complex series of micro-climates which are characteristic of the Hawaiian Islands. Because of this variability it becomes difficult to arrive at characters which will delimit the populations.

TABLE 2

A COMPARATIVE ANALYSIS OF THE GENERA *Neraudia* AND *Pouzolsia.*

CHARACTER	NERAUDIA	POUZOLSIA
Sex condition of flowers	Dioecious	Monoecious, rarely dioecious
Flower arrangement	Axillary, unisexual clusters	Axillary heads, spikes, or cymes; sexes mixed in same inflorescence
Staminate calyx	4-parted	3-4-5-parted
Stamens	Four	Three to five
Apex of perigone	0-4 toothed	2-4 toothed
Ovule	Erect	Erect
Pistillate calyx	Fleshly, free from achene	Greatly enlarged or scarcely changed
Habit	Shrub or small tree	Trees, shrubs, or herbs
Leaf arrangement	Alternate	Alternate or opposite
Leaf margin	Undulate, dentate, or entire	Dentate or entire
Venation of leaves	3-nerved	3-nerved
Cystoliths	Disciform	Disciform

Neraudia has been a problem of this sort and it is apparent that instead of very precise, definite, constant characters which operate throughout the genus, there is a tendency for differences to be expressed in sets of characters. Furthermore, a character which is constant in one group may prove to be quite variable in another. Each population is influenced by its own set of environmental factors and each has its own particular genetical makeup. These two sets of factors alone are enough to insure that the degree of variability and the organ affected may be quite different in each population.

Leaf shape has been used to distinguish some of the groups in this genus and is occasionally a usable character since some of the groups show tendencies toward particular leaf shapes. However, in most of the groups leaf shape exhibits so much variability that it is not satisfactory as a key character. In some groups ovate to elliptic leaves with intermediate shapes occur in the same collection; in such groups, at least, leaf shape is an unreliable character. Leaf size is expected to show some variation in all genera but in this genus the extremes of lengths and widths are often great in the same group. The shape of the base and of the apex of the leaves is often more constant but this is not a completely reliable key character either.

Vesture of the leaves has proved the most reliable character in the genus and is, I believe, genetical in nature. Even the quantity of pubescence present seems to be relatively constant; but it is the type of hair, distribution, posture, and orientation of the hairs that are used as key characters. The hairs are always simple but may be short and uncinate, longer and arcuate, curving and bending irregularly, or straight. In some groups the lower leaf surface is glabrous or sub-glabrous; in others the pubescence is restricted to the venation but in most groups this is not so. The pubescence on the upper leaf surface is always of the same type as that below but is more sparse and usually appressed. The consistency of the leaves varies somewhat, insofar as it has been possible to observe it in fresh and dried collections, but it is constant enough to be used in identifying some groups.

The venation of the leaves is of two general types and on this basis the genus is separable into two parts. If a leaf is held against a strong light the fine details of the venation are clearly discernible with or without magnification. Because of the prominence of the secondary vein branches the first type appears to be a coarse-meshed net within the intervals of the primary vein branches, whereas the second type, due to the equal or greater prominence of the tertiary

TABLE 3
DISTRIBUTION OF SPECIES AND VARIETIES OF *Neraudia*.

	KAUAI	OAHU	MAUI	LANAI	MOLOKAI	HAWAII
N. melastomaefolia						
var. *melastomaefolia*	--	x	--	--	--	--
var. *uncinata*	--	x	--	--	--	--
var. *Gaudichaudii*	--	x	--	--	--	--
var. *pubescens*	x	--	--	--	--	--
var. *parvifolia*	--	x	--	--	--	--
var. *pallida*	--	--	x	--	--	--
N. angulata						
var. *angulata*	--	x	--	--	--	--
var. *dentata*	--	x	--	--	--	--
N. kauaiensis						
var. *kauaiensis*	x	--	--	--	--	--
var. *Helleri*	x	--	--	--	--	--
N. ovata	--	--	--	--	--	x
N. sericea	--	--	x	x	x	--
Total number of groups per island	3	6	2	1	1	1

branching gives the impression of a very fine-meshed net. The principal veins and their first branches may be strongly salient or only slightly raised. The leaves may be either palmately nerved or triplinerved and this character is of some use in distinguishing certain groups.

The flowers are of two sexes borne on separate plants. Flowers of either sex may be sessile or short-pedicelled but are constantly either one or the other. The calyx of all pistillate flowers is fused so that the ovary is loosely enclosed in the inflated calyx. The tip of this perigynium is always elongated into a beak through which the style passes. The stigma is filiform and covered more or less completely with stout stigmatic hairs which serve as receptive surfaces for the pollen. The pubescence on the exterior surface of the calyx is ordinarily of the same type and posture as that found on the lower leaf surface. After fertilization of the single, erect, basally attached ovule the ovary undergoes certain characteristic changes in form and becomes hard and bony. More striking though is the change in the calyx, which enlarges to many times its original size, becomes fleshy, and turns red at maturity. It is variable in shape and ranges in size from 3 or 4 millimeters to as much as a centimeter or more in height.

The achene characters are used to distinguish species and groups of subspecific rank. The dimensions and shape of the basal and apical portions of the achenes are usable characters but only if completely mature forms are available. The apical portion may be conic or depressed-conic and may be separated from the basal portion incompletely or completely by a deep or only slight constriction. The basal portion may be flattened or convex and its outer margin may be involute or plane.

The staminate flowers and pistillate flowers may be borne on pedicels. When they are so borne the pedicels are slender-filiform but because of their shortness (0.5–2.0 mm.) are most easily observed at nodes where flowers and fruits have been shed. Occasionally the scars of fallen sessile flowers become somewhat swollen but differ from pedicels in their greater thickness and shortness.

The calyx of the staminate flowers consists of four navicular lobes which separate at maturity to release the four, opposite, inflexed stamens. The filaments are folded inward so that the connective is nearest the center of the flower. At maturity the filaments, when released by the opening of the calyx segments, snap outward explosively and at the same time the pollen is discharged in a small white cloud. From this method of pollen discharge and the presence of the feathery stigma described above, it may be safely postulated that the pollination agent is the wind since both of these mechanisms are adaptations for wind pollination. The staminate flowers have few distinctive characters other than different types of hair on the calyx and the consistency of the lobes.

TAXONOMIC CATEGORIES

Of all biological terms "species" is undoubtedly one of the most difficult to define in a manner which is satisfactory and acceptable to even a small group of taxonomists. The concept itself is reasonably clear but the problem of its definition must still be resolved by the individual worker. Each must decide what his basic criteria for the recognition of a species shall be and then attempt to apply his concept in the field as well as in the laboratory. Experience and contacts with other taxonomists will usually force certain modifications of the original concept so that the ultimate interpretation may be quite unlike that originally held. In this paper a species is interpreted as a population of individuals showing constant morphological differences distinct from those of other populations in the genus.

Varieties are considered to be units within the main specific population which show a character or characters peculiar to themselves but these differences are often overlapping to some degree, i. e., varieties lack the distinctness which characterizes the specific unit. The varietal category has not been used to replace

that of the subspecies nor is the category in any way related to the horticultural usage of the term. Some workers have advocated the abolition of the term "variety" and have used the argument that there is confusion in its usage in formal taxonomy and in horticulture. However, it is a category sanctioned in the International Rules and the "confusion" is mostly in the minds of the workers who advocate abolishing the term. A variety may arise by hybridization where two populations meet geographically, or it may be produced as a result of population changes induced by geologic or climatic isolation, although the origin in either manner may be obscured by the disappearance of intermediate forms. In general, it is assumed that varieties are incipient species.

Although subspecies and forms have not been recognized in the study of this group, it seems advisable to attempt a definition of them. The subspecies category seems to be applied best to groups of varieties with less than specific distinctness but more distinctness than a variety. Forms are taxonomic units (within either the specific or varietal population) which exhibit morphological differences of less significance than those shown by a varietal, subspecific, or specific group. Such entities appear sporadically within populations of higher categories. The difficulty lies in the recognition of forms, for unless extreme care is exercised each ecad may receive recognition as a form and be named and described as such. Forms are considered varieties in the embryonic state of differentiation.

SYSTEMATIC AND DESCRIPTIVE TREATMENT

Genus NERAUDIA Gaudichaud

Neraudia Gaudichaud, Freyc. Voy. Uranie Bot.: 500, 1830.

Erect, climbing, spreading, or vining shrubs or small trees with watery-milky or very milky sap; branches usually arcuate but sometimes erect and straight, branchlets green with pinkish tint at growing tip, pubescence very sparse to abundant, hairs erect or appressed, grayish or whitish or almost hyaline; petioles 0.5–6 cm. long, terete, sparsely or abundantly pubescent, hairs erect or appressed, straight or irregularly bending and curving. Leaf blades 3–19.5 cm. long, 1.5–7 cm. wide, elliptic, lanceolate, oblance-elliptic, elliptic-ovate, ovate, slightly obovate, or oval, thin or membranous to thick-coriaceous, palmate or triplinerved; upper surface glabrous or with few to many erect or appressed hairs, cystoliths disciform, even with upper leaf surface, pulvinate, or strongly salient with rounded or sharply truncate apex (in dried material), lower surface glabrous or with few hairs largely restricted to venation, or with many erect or appressed hairs over entire lower surface, or with dense covering of erect to suberect, irregularly curving and bending hairs, or puberulent; principal veins and primary branches of veins slightly or strongly salient, margin entire, dentate, repand, or irregularly undulate; base cuneate, cuneate-decurrent, obtuse, or sub-cordate, apex abruptly acute to long-acuminate or tapering gradually into an acute or long-acuminate tip. Pistillate flowers sessile or on pedicels 0.5–2 mm. long, some flowers with subtending bract, calyx lobes fused into perigynium with tip drawn out into beak, perigynium pilosulose with few, ascending, appressed hairs or many erect hairs, beak flaring or narrowing upward, irregularly laciniate to four acute-toothed, to four acuminate-toothed, to three-toothed collariform, stigma 2–8 mm. long, receptive stigmatic hairs on all surfaces or one side lacking stigmatic hairs. Achene enclosed in accrescent, thin to thick-fleshy, smooth, or sharply angled and ridged calyx, achene 1–3.5 mm. tall, usually with distinct apical and basal portions, apical portion conic, depressed-conic, hemispheric, separated from basal portion by deep acute constriction or by very shallow or slight constriction or without definite, complete constriction, basal portion flat, depressed-convex, or convex, outer margin plane or involute, seed ellipsoid or ovoid, constricted in upper part or entire. Staminate flowers sessile or on pedicels 0.5–2.5 mm. long, four calyx segments cohering

in bud but separating at maturity, thin to thick, navicular, pilosulose, hairs appressed or erect, few to many, hairs straight or uncinate, 2–6 mm. long, 1–2 mm. wide, filaments 2–5 mm. long, folded inward in bud, strap-shaped, anthers two-celled, reniform, each sac 0.8–2 mm. long, 0.5–1 mm. wide.

KEYS TO THE SPECIES AND VARIETIES OF NERAUDIA

Instructions for Use of Keys

As collected, plants of this genus may be sterile, may have staminate flowers or pistillate flowers, may lack fruit, or may have both pistillate flowers and fruit. Because of this variety, keys which are intended to identify plants collected in any condition have been constructed. There undoubtedly will be collections which may prove troublesome but it is felt that the keys, if carefully used, will identify collections of the groups recognized. The heading of each key indicates the type of collection for which the key was constructed. In all cases the characters used in the keys apply to mature, dried, normally developed structures and it is important to recall this when attempting to use the keys. For example, the achene characters which are important appear sometimes only in the completely mature achenes.

In this study a dissecting microscope has been used and those who use the keys must do likewise. The necessary magnifications for studying pubescence and flowers in this genus are about 36–72×, whereas pedicels or achene details can best be observed with about 12× magnification. The details of the reticulation of the leaves have been used in the keys; the reticulation is most readily and accurately observed by holding a leaf against a strong light source, with or without magnification.

The length of the hairs has been referred to in some places as "short" or "long": the term "long" refers to hairs of about 1–2 mm. or longer; the term "short" refers to those considerably less than 1 mm. long.

The first key is based upon typical, full-flowering material and should be used in attempting to identify such material only. Collections in the vegetative state or in a state of transition between vegetative activity and flowering should be identified by Key II.

Glossary of Terms Employed

Basal portion—applied to the lower expanded portion of the achene.

Depressed-conic—applied to the apical portion of some of the achenes which appear to have been depressed apically so that the sides are rounded and bulging.

Interval—the portion of a leaf blade enclosed by any degree of branching of the venation, e. g., a primary interval is that part of the leaf blade within a part of the primary branching.

Perigynium—the calyx of the pistillate flower fused into a bladder which surrounds the ovary.

Pilosulose—pilose, but with the hairs short.

Primary branches—first degree of branching of the principal veins.

Principal veins—midrib and two equally strong laterals.

Puberulent—covered with fine and short, almost imperceptible down.

Sericeous—covered with many shining, silky, appressed or sub-erect, straight hairs.

Triplinerved—principal veins diverging any distance above the leaf base.

KEY I

General Key to Species and Varieties of *Neraudia*

1.	Lower leaf surface glabrous, subglabrous with only few hairs largely restricted to venation, or with long, evenly distributed, appressed or sub-appressed hairs	2
	Lower leaf surface evenly puberulent, sericeous, or pilosulose with more or less dense cover of irregularly curving and bending hairs	7
2 (1).	Flowers of one or both sexes all, or at least some, pedicelled; pedicels 0.5–2 mm. long	3
	Flowers of both sexes sessile	5

3 (2). Lower leaf surface with many rather long, evenly distributed hairs. Uncinate hairs lacking on all plant parts ..... *N. melastomaefolia* var. *Gaudichaudii*

Lower leaf surface with few or no hairs except on veins; if present, in intervals and very short; uncinate hairs present on leaves and calices 4

4 (3). Leaves and calyx lobes coarse, thick; venation on lower leaf surface markedly salient; leaves usually triplinerved. Apical portion of achene depressed-conic, basal portion thickened. Calyx of staminate flowers with about equal proportion of straight appressed and shorter, erect, uncinate hairs ..... *N. melastomaefolia* var. *melastomaefolia*

Leaves and calyx neither coarse nor thick; venation on lower leaf surface not very salient; leaves usually palmately nerved. Apical portion of achene usually conic, basal portion thin, often flat. Calyx of staminate flowers with all or most of the hairs short, erect, uncinate ..... *N. melastomaefolia* var. *parvifolia*

5 (2). Pubescence on lower leaf surface largely restricted to venation, primary intervals without long hairs. Outer margin of achene not involute 6

Pubescence on lower leaf surface not restricted to venation, primary intervals with many long, appressed or sub-erect hairs distributed over entire surface. Outer margin of achene involute ..... *N. melastomaefolia* var. *pubescens*

6 (5). Secondary veins and smaller vein branches of lower leaf surface with many short, erect or sub-erect, uncinate hairs; lower leaf surface paler but not markedly pallid when dry ..... *N. melastomaefolia* var. *uncinata*

Venation of lower leaf surface not as above, glabrous or sparsely pilosulose with few ascending, appressed hairs; lower leaf surface very pallid when dry ..... *N. melastomaefolia* var. *pallida*

7 (1). Lower leaf surface white- or whitish-sericeous, usually conspicuously viscid. Calyx of pistillate flowers distinctly angled, that enclosing mature achene thick-fleshy and with many fleshy ridges and angles 8

Lower leaf surface pilosulose with hairs irregularly curving and bending or lower leaf surface puberulent 9

8 (7). Leaf margin always entire, pubescence on lower leaf surface appressed, oriented centripetally in primary intervals, mostly directed toward margin and producing a geometrically uneven sheen ..... *N. angulata* var. *angulata*

Leaf margin completely dentate, partly dentate, or rarely entire; pubescence on lower leaf surface mostly erect or sub-erect but upper part of each hair somewhat arcuate, pubescence oriented much as in var. *angulata* but geometrically uneven sheen not marked ..... *N. angulata* var. *dentata*

9 (7). Lower leaf surface puberulent. Outer margin of achene involute ..... *N. ovata*

Lower leaf surface with more or less dense cover of grayish pubescence, hairs irregularly curving and bending or almost straight. Outer margin of achene not involute 10

10 (9). Leaf margin entire 11

Leaf margin irregularly undulate (only staminate flowers known) ..... *N. kauaiensis* var. *Helleri*

11 (10). Apical portion of achene conic without deep constriction separating it from basal portion. Leaf base usually sub-cordate; secondary branching of veins forming the conspicuous reticulation in primary intervals ..... *N. kauaiensis* var. *kauaiensis*

Apical portion of achene depressed-conic with deep constriction separating it from basal portion. Leaf base usually cuneate; tertiary branching of veins forming the conspicuous reticulation in primary intervals ..... *N. sericea*

KEY II

For Identification of Non-fruiting Pistillate or Sterile Plants

1. Secondary branching of veins forming conspicuous reticulation of leaf, that formed by the tertiary branching less conspicuous or obscure, giving the impression of a coarse-meshed net within the primary intervals 2

Tertiary branching of veins forming the conspicuous reticulation of leaf, that formed by the secondary branching not more conspicuous and often less conspicuous than that formed by the tertiary branching, giving the impression of a fine-meshed net within primary intervals 14

2 (1). Calyx of pistillate flower angled. Lower leaf surface sericeous.... 3

Calyx of pistillate flower not angled. Lower leaf surface not sericeous . 4

3 (2). Leaf margin dentate, partly dentate, or rarely entire. Pubescence on lower leaf surface mostly sub-erect except that upper part of each hair is somewhat arcuate .....*N. angulata* var. *dentata*

Leaf margin always entire. Pubescence mostly appressed and directed toward margin, oriented centripetally in primary intervals producing a conspicuous geometrically uneven sheen ....*N. angulata* var. *angulata*

4 (2). Calyx beak attenuate apically. Lower leaf surface not obscured by pubescence (or if partly or completely obscured, leaf base sub-cordate or leaf margin irregularly undulate) 5

Calyx beak expanded apically. Lower leaf surface obscured by pubescence (if not, or only in-completely obscured, lower surface puberulent or lower surface markedly pallid when dry) 13

5 (4). Lower leaf surface with little or no pubescence; when present, hairs largely restricted to principal veins and primary vein branches; infrequently very short hairs in vein intervals 6

Lower leaf surface generally pubescent, hairs not restricted to veins but generally distributed over entire surface 9

6 (5). Flowers all, or at least some, pedicelled; pedicels slender, 0.5–2 mm. long, often persistent on sterile plants recently fertile 7

Flowers all sessile 8

7 (6). Leaves thin, palmate; apex abruptly acute to acuminate; base often obtuse or sub-obtuse. Calyx lobes thin ....*N. melastomaefolia* var. *parvifolia*

Leaves thick, usually triplinerved; apex evenly acute to acuminate; base usually cuneate. Calyx lobes thickish, particularly at tips..*N. melastomaefolia* var. *melastomaefolia*

8 (6). Lower leaf surface with few to many erect or sub-erect, very short, uncinate hairs on venation other than principal veins and primary branches; paler below when dry but not markedly pallid. Leaf apex evenly acuminate ...*N. melastomaefolia* var. *uncinata*

Lower leaf surface without uncinate hairs, entirely glabrous or with few, appressed hairs on principal veins; when dry, markedly pallid below. Leaf apex usually abruptly acuminate ....*N. melastomaefolia* var. *pallida*

9 (5). Leaves with dense covering of irregularly curving and bending, erect hairs on lower leaf surface, or hairs almost straight 10

Leaves without above type of pubescence but with few to many long, evenly distributed, ascending, appressed or sub-erect hairs 12

10 (9). Leaf margin entire 11
Leaf margin irregularly undulate (only staminate plant known) .. ..*N. kauaiensis* var. *Helleri*

11 (10). Leaf base usually rotund, subcordate or obtuse. On upper leaf surface at junction of principal veins, tuft of hair always erect. On veins of lower leaf surface, hairs erect, irregularly bending, or almost straight ....*N. kauaiensis* var. *kauaiensis*
Leaf base not rotund or sub-cordate, usually cuneate. On upper leaf surface at junction of principal veins, tuft of hair appressed. On veins of lower leaf surface, hairs ascending, mostly appressed, and nearly straight .....*N. sericea*

12 (9). Leaves usually palmately nerved.. ..*N. melastomaefolia* var. *pubescens*
Leaves usually triplinerved ....*N. melastomaefolia* var. *Gaudichaudii*

13 (4). Leaves elliptic or oblance-elliptic, entirely glabrous or with few ascending, appressed hairs on midrib of lower leaf surface; when dry, lower leaf surface markedly pallid ....*N. melastomaefolia* var. *pallida*
Leaves not as above, with dense covering of erect, irregularly curving and bending hairs on lower leaf surface.....*N. sericea*

14 (1). Lower leaf surface puberulent, hairs very short, and fine, almost hyaline .....*N. ovata*
Lower leaf surface densely pilosulose, hairs whitish or grayish and longer (more than 0.8 mm.) .....*N. sericea*

KEY III

For Identification of Pistillate Plants with Flowers and Fruit

1. Calyx beak attenuate appically..... 2
Calyx beak expanded apically..... 13

2 (1). Calyx of flower angled; calyx of mature fruit very thick-fleshy, sharply ridged, and angled. Lower leaf surface sericeous 3
Calyx of flower not angled; calyx of mature fruit not thick-fleshy, sharply ridged, or angled 4

3 (2). Leaf margin dentate, partly dentate, or, rarely, entire. Pubescence on lower leaf surface sub-erect, hairs mostly arcuate in upper part, directed mostly toward margin, geometrically uneven sheen on lower surface not marked ....*N. angulata* var. *dentata*
Leaf margin always entire. Pubescence on lower leaf surface strictly or mostly appressed and oriented centripetally in primary intervals and producing a marked geometrically uneven silvery sheen ....*N. angulata* var. *angulata*

4 (2). Outer margin of basal portion of achene not involute 5
Outer margin of basal portion of achene involute 11

5 (4). Apical portion of achene depressed-conic or hemispheric ... 6
Apical portion or achene not depressed-conic or hemispheric but more or less conic with blunt or sharp tip 10

6 (5). Apical portion separated from basal portion by deep transverse constriction. Lower leaf surface densely pilosulose, hairs erect, irregularly curving and bending .. ..*N. sericea*
Apical portion separated by only slight, obtuse constriction from basal portion or lacking definite, complete constriction. Lower leaf surface not densely pilosulose, hairs when present appressed to sub-erect 7

7 (6). Lower leaf surface with many rather long, evenly distributed hairs over entire surface ....*N. melastomaefolia* var. *Gaudichaudii*
Lower leaf surface with hairs mostly restricted to veins, if in intervals, hairs very short 8

8 (7). Leaves thick, often triplinerved; veins very strongly salient below. Flowers of both sexes with pedicels; calices thick, particularly at tips of lobes of staminate calyx .....*N. melastomaefolia* var. *melastomaefolia*

Leaves not thick, usually palmate; venation not strongly raised below. Flowers sessile; calices thin 9

9 (8). Many very short, erect or sub-erect, uncinate hairs on veins other than principal veins and primary branches. Apical portion of achene depressed-conic. Leaves drying paler below but not markedly pallid ....*N. melastomaefolia* var. *uncinata*

No uncinate hairs present on lower leaf surface. Apical portion of achene hemispherical. Leaves drying markedly palid below ....*N. melastomaefolia* var. *pallida*

10 (5). Flowers of both sexes with slender pedicels, 0.5–2 mm. long. Leaf base very often obtuse or subobtuse, sometimes cuneate. Very few hairs on lower leaf surface and these restricted for most part to venation. Staminate calyx with all or almost all hairs erect to suberect, uncinate ....*N. melastomaefolia* var. *parvifolia*

Flowers of both sexes usually sessile, staminate flowers sometimes with short pedicels. Leaf base rotund, usually sub-cordate. Lower leaf surface with many erect, irregularly curving and bending or almost straight hairs covering entire surface. Staminate flowers pilosulose, hairs many, erect to sub-erect, ascending ....*N. kauaiensis* var. *kauaiensis*

11 (4). Lower leaf surface pubescent. Calyx of staminate flowers with most hairs straight 12

Lower leaf surface glabrous or very sparsely pilosulose, few ascending, appressed hairs on venation. Calyx of staminate flowers with all or most hairs short, erect, uncinate ....*N. melastomaefolia* var. *parvifolia*

12 (11). Lower leaf surface pilosulose, hairs evenly distributed, ascending, appressed or sub-erect. Achene 2.5–3.5 mm. long, averaging 3 mm. long; apical portion conic, without definite, complete constriction from raised basal portion. Calyx surrounding mature achene, about 6 mm. long when dry ..*N. melastomaefolia* var. *pubescens*

Lower leaf surface puberulent, hairs erect or sub-erect. Achene 2–3 mm. long, usually 2 mm. long; apical portion depressed-conic, separated from depressed-convex basal portion by deep, obtuse or acute constriction. Calyx surrounding mature achene 4 mm. long or less .....*N. ovata*

13 (1). Lower leaf surface glabrous or with very few hairs on principal veins. Calyx sparsely pilosulose, hairs few, ascending, appressed. Lower leaf surface drying markedly pallid ..*N. melastomaefolia* var. *pallida*

Lower leaf surface puberulent or pilosulose with very many erect or sub-erect, irregularly curving and bending hairs. Calyx densely pilosulose, hairs appressed or suberect. Lower leaf surface not drying markedly pallid 14

14 (13). Outer margin of achene involute, constriction separating apical and basal portion usually obtuse. Puberulent on lower leaf surface .....*N. ovata*

Outer margin of basal portion of achene plane, constriction separating apical portion usually deep and acute. Lower leaf surface with dense covering of grayish, irregularly curving and bending hairs .....*N. sericea*

KEY IV

For Identification of Staminate Plants

1. Lower leaf surface sericeous 2

Lower leaf surface glabrous or pilosulose 3

2 (1). Leaf margin entire; pubescence on lower leaf surface strictly or mostly appressed, centripetally oriented in primary intervals, producing a geometrically uneven silvery sheen ....*N. angulata* var. *angulata*

Leaf margin dentate, partly dentate, or rarely entire; pubescence on lower leaf surface sub-erect, hairs

straight except arcuate apically, mostly centripetally oriented but geometrically uneven sheen less marked ....*N. angulata* var. *dentata*

3 (1). Hairs on calyx lobes all or mostly straight 4
Hairs on calyx lobes all or almost all short, erect, uncinate; occasionally a few longer, straight, appressed hairs on margins ....*N. melastomaefolia* var. *parvifolia*

4 (3). Few to many short, erect, uncinate hairs present on calyx mixed with numerous longer, straight hairs.. 5
No uncinate hairs on calyx lobes (or staminate flowers unknown) 8

5 (4). Lower leaf surface with few hairs only, largely restricted to venation 6
Lower leaf surface with many hairs over entire surface 7

6 (5). Flowers sessile; calyx lobes thin. Leaves thin, usually palmate; veins not very strongly raised below; many short, erect or suberect, uncinate hairs on secondary and smaller vein branches ....*N. melastomaefolia* var. *uncinata*
Flowers usually pedicelled; calyx lobes thick, especially at tips. Leaves thick, often triplinerved; veins very strongly salient below; uncinate hairs, if present, scattered indiscriminately on lower leaf surface .....*N. melastomaefolia* var. *melastomaefolia*

7 (5). Calyx lobes membranous; lower leaf surface puberulent .....*N. ovata*
Calyx lobes thin but not membranous; lower leaf surface densely pilosulose, hairs white or grayish, irregularly curving and bending .....*N. sericea*

8 (4). Lower leaf surface with many hairs; not drying very pallid below ... 9
Lower leaf surface with few or no hairs; drying very pallid below (staminate flowers unknown) .. ....*N. melastomaefolia* var. *pallida*

9 (8). Leaf margin entire 10
Leaf margin irregularly undulate .. ..*N. kauaiensis* var. *Helleri*

10 (9). Leaf base usually rotund, sub-cordate; pubescence on lower leaf surface erect, more or less irregularly curving and bending..... .....*N. kauaiensis* var. *kauaiensis*
Leaf base cuneate; pubescence on lower leaf surface appressed or sub-erect, entirely straight 11

11 (10). Calyx usually over 4 mm. long, averaging 5 mm. long. Leaves palmately nerved ....*N. melastomaefolia* var. *pubescens*
Calyx 3–4 mm. long, averaging less than 4 mm. Leaves usually triplinerved .....*N. melastomaefolia* var. *Gaudichaudii*

Neraudia melastomaefolia Gaudichaud, Freyc. Voy. Uranie Bot.: 500, pl. 117, 1830.

Boehmeria melastomaefolia (Gaud.) H. & A., Bot. Beechey Voy. 2: 96, 1832.

Boehmeria melastomaefolia (Gaud.) Endl., Wien Mus. Naturgesch., Ann. 1: 165, 1836.

Boehmeria melastomaefolia (Gaud.) Steudel, Nom. Bot. 2: 192, 1841.

Shrub or small tree up to 6 m. tall, usually shrub less than 4 m. tall, main stem 1–5 cm. in diameter at base. Upper branchlets pilosulose, with few to many erect or appressed hairs, branchlets arcuate, lax, and pendent or erect. Petioles 1–5.5 cm. long, glabrous or pilosulose with few to many erect or appressed hairs. Leaf blades 4–19.5 cm. long, 1.5–7 cm. wide, elliptic, oblance-elliptic, lanceolate, elliptic-ovate, ovate, or oval, thin to thick, chartaceous or coriaceous, palmate or triplinerved; upper surface glabrous or sparsely pilosulose with few appressed, ascending hairs, lower surface glabrous or pilosulose, hairs few to many, appressed or sub-erect, ascending, restricted to venation or evenly distributed over lower leaf surface, and none to many shorter erect or sub-erect, uncinate hairs; principal veins and primary branches slightly to markedly salient below; margin entire, base cuneate or cuneate-decurrent to obtuse or sub-obtuse or slightly sub-cordate, leaf tip gradually or abruptly tapering into an acute

or acuminate or long-acuminate apex. Pistillate flowers sessile or with filiform pedicels 0.5–2 mm. long; calyx pilosulose, with few ascending, appressed hairs, and with or without some shorter, erect, uncinate hairs; beak usually attenuate apically, sometimes expanded, four-toothed at apex; stigma 2–8 mm. long, receptive on all surfaces or stigmatic hairs absent on one side. Achene 1.0–3.5 mm. long, apical portion sharply conic to depressed-conic, separated from basal portion by slight or incomplete constriction or without constriction, basal portion flattened, depressed-convex or convex, 2–3 mm. in diameter, plane or involute at outer margin; seed ellipsoid or ovoid. Staminate flowers sessile or pedicelled, with four navicular, acutely or acuminately tipped lobes, 4–6 mm. long, 1.5–2.0 mm. wide, pubescence of lobes mostly straight, ascending, appressed or mostly erect or sub-erect uncinate hairs; pistil rudiment 0.3–2.0 mm. long, filaments 2.5–5.0 mm. long, 0.5–1.0 mm. wide, connective swollen-fleshy or unswollen; anthers reniform, 1.5–2.0 mm. long, 0.8–1.0 mm. wide.

The subspecific entities which comprise this species are distinct enough to be considered varieties but to accord them higher rank is, I believe, without justification. I feel that species should show constant morphological characters with no or few intermediate forms whereas varieties very often have such intermediate forms. The varieties *melastomaefolia, uncinata, pubescens,* and *Gaudichaudii* are superficially similar but variety *parvifolia* has a different aspect.

Hillebrand (1888) included all the groups which he knew in the one species, *N. melastomaefolia,* with a variety, *parvifolia.* This variety was, as Hillebrand's citation shows, a transfer of Wawra's forma *parvifolia* of *N. sericea* (as applied by Wawra) to *N. melastomaefolia.* The transfer is herein accepted and the name applied to one of the varietal groups.

Certain inaccuracies in Gaudichaud's plate have become apparent on examination of his material. The leaves are illustrated as palmate with blunt apices, but the leaf tips in his material are sharp and most of the leaves are triplinerved to some degree. The flowers on the pistillate branch of his habit sketch are strikingly similar to those of *Pipturus* and I believe that material of this genus was used for this part of the plate. Gaudichaud's artist shows stipules which are interpetiolar with the appearance of thorns rather than intrapetiolar, membranous structures. The bract-like structure at the base of his young pistillate flower is not uniformly present. The margin of the apex of the calyx neck is actually toothed rather than entire, and the fleshy calyx surrounding the achene is depressed-globose instead of convex. The achene is not stalked and is attached to the calyx on the ventral surface except at the outer margin. The seed is represented in his plate as having a constriction and the seed cavity as extending to the apex of the achene but neither is true. The staminate flowers are really oblong-elliptic rather than globose and the tips of the calyx lobes are much thicker than illustrated.

Neraudia melastomaefolia Gaud. variety **melastomaefolia** Cowan, *var. nov.*

Fig. 1

Neraudia melastomaefolia Gaud., Freyc. Voy. Uranie Bot.: 500, pl. 117, 1830.

Description of Gaudichaud's material: Upper branchlets with many ascending, appressed hairs. Petioles 1.0–4.5 cm. long with few to many ascending, appressed hairs. Leaf blades 8.5–12.0 cm. long, 2.5–4.5 cm. wide, narrow elliptic to oval, thick, mostly triplinerved, glabrous above, lower surface with few ascending, appressed hairs on principal veins, margin entire, base cuneate-decurrent, or only cuneate, apex evenly long-acuminate, principal veins very strongly raised on lower leaf surface. Pistillate flowers on slender pedicels 0.5–2.0 mm. long; calyx with many ascending, appressed hairs and some erect, uncinate hairs; beak attenuate apically; stigma non-receptive on one side. Staminate flowers on pedicels 0.5–1.5 mm. long; calyx with both short, erect, uncinate hairs and longer straight, ascending, appressed hairs, lobes thick,

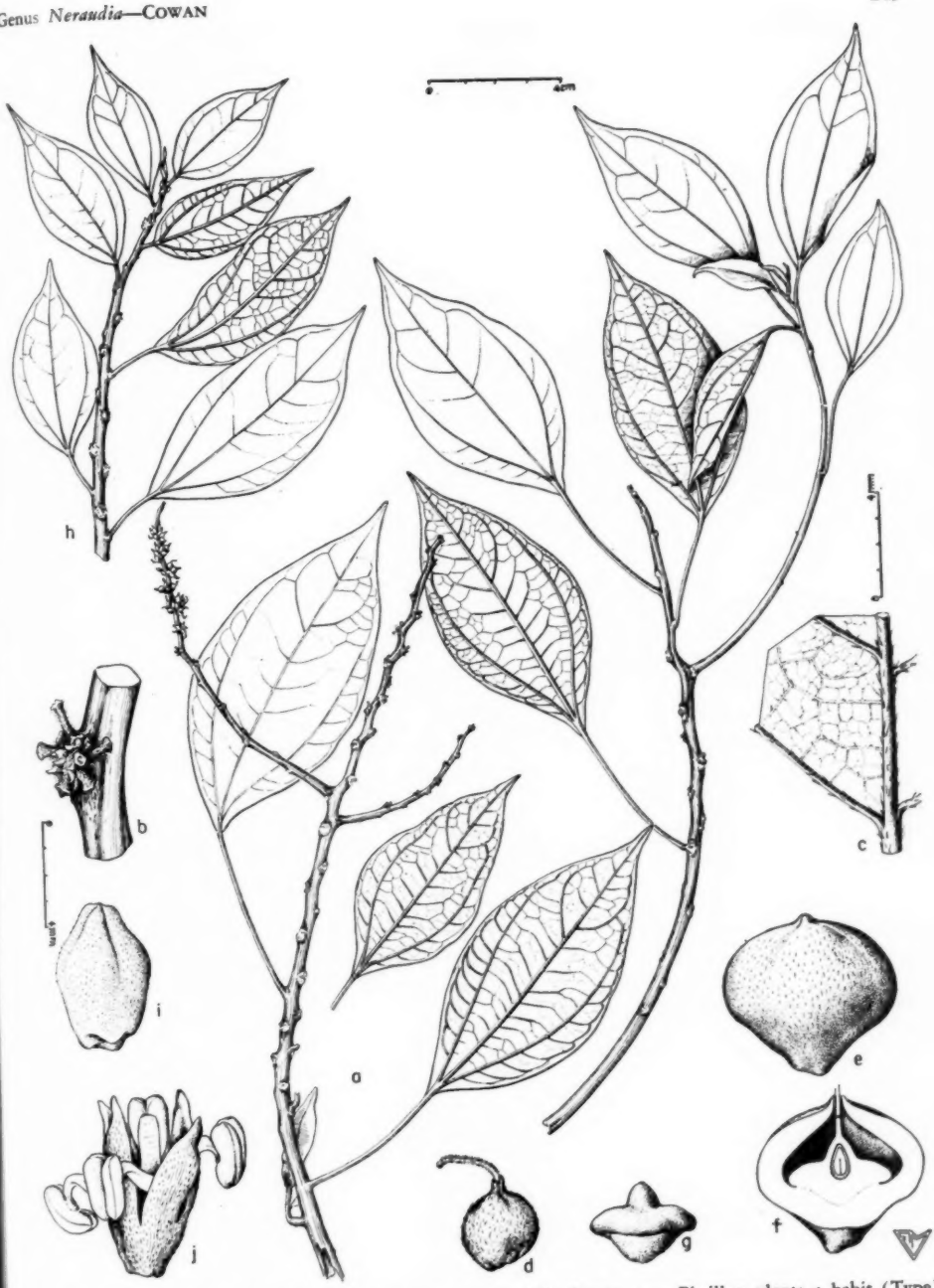

FIG. 1. *Neraudia melastomaefolia* Gaud. var. *melastomaefolia* Cowan. *a–g*, Pistillate plant: *a*, habit (Type); *b*, one node (Type); *c*, portion of lower leaf surface (Type); *d*, young flower (Type); *e*, mature calyx enclosing achene (*Frederick 207*); *f*, long section through mature calyx and achene (*ibid.*); *g*, external view of achene. *h–j*, Staminate plant: *h*, habit (*Gaudichaud*); *i*, young flower (*St. John 22568*); *j*, mature flower (*ibid.*).

especially at tips. No mature achenes present.

Description of all material examined: Spreading shrub 2–6 m. tall, about 3 cm. in diameter at base; upper branchlets pilosulose with many ascending, appressed hairs. Petioles 1.0–4.5 cm. long, averaging about 2 cm. long, pilosulose with many appressed, ascending hairs. Leaf blades 6–13 cm. long, 2.5–7.0 cm. wide, averaging 9 cm. long, 4.5 cm. wide, narrow elliptic, elliptic-ovate, oval, or slightly obovate, thick, sub-coriaceous or coriaceous, very often triplinerved, above glabrous, below sub-glabrous with only few straight, ascending, appressed hairs mostly restricted to veins, sometimes with very short, scattered hairs in intervals; margin entire, base cuneate and decurrent or sub-obtuse, apex acute or acuminate, tip of apex sharp or blunt, principal veins very strongly raised. Pistillate flowers with pedicels 0.5–2.0 mm. long; calyx sub-glabrous with very few ascending, appressed hairs; beak attenuate apically, apex with four acute or acuminate teeth; stigma 2–3 mm. long, one side usually lacking receptive stigmatic processes. Achene 2.0–2.5 mm. long, averaging 2 mm., apical portion depressed-conic, separated from basal portion by abrupt obtuse constriction or without obvious constriction, basal portion smooth, thick, outer margin plane, 2.5–3.0 mm. in diameter, seed ovoid. Staminate flowers with pedicels 0.5–2.0 mm. long; calyx lobes thick, particularly at tips, pilosulose with many ascending, appressed hairs and with or without some erect uncinate hairs, lobes 3–5 mm. long, 1.5–2.0 mm. wide, apex acute or acuminate; filaments 3.5–5.0 mm. long, 0.5–1.0 mm. wide, tapering at apex into broader, fleshy, swollen connective; anthers 2 mm. long, 1 mm. wide.

Type: Gaudichaud, "In insulis Sandwicensibus, cum sequente (alt. 350–400 hex.)." (In Sandwich Islands, altitude 1,500–2,400 feet.) (Deposited in Museum National d'Histoire Naturelle de Paris [P].)

Range: Island of Oahu, Waianae Range, moist regions, 2,000–3,450 feet altitude.

Specimens examined

Data complete: Haleauau Gulch, Mt. Kaala, *St. John 22269, 22270* (Ho); Mt. Kaala, *Degener 18190* (NY); Mt. Kaala, *Cowan and St. John 333* (Ho); Puu Kalena, *St. John 22568* (Ho); Puu Kalena, *Donaghho* (Ho); Hapapa Gulch, *Russ* (Ho); Kanehoa, *Frederick 207, 208, 209, 210* (Ho); Kanehoa, *Cowan 1054, 1057* (Ho); Makaha Valley, *Forbes* (Ho); Oahu, Waianae, *Faurie 515* (P, Ho).

Data not complete: Honolulu, Sandwich Islands, *Hillebrand* (K); Oahu, *Seeman 2260* (G, K, Ho); *Mann & Brigham 220* (GH, G, Ho); Woahoo, *Macrae* (K); *Gaudichaud 208* (Bonite Voyage) (G); *Remy 197*, Maui (data very questionable) (P).

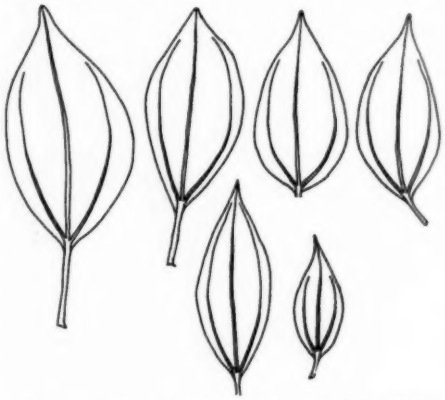

FIG. 2. Outlines of leaves to show variation in leaf shape and in venation in *Neraudia melastomaefolia* Gaud. var. *melastomaefolia* Cowan (approx. ⅓).

This group seems in several ways to be intermediate between varieties *uncinata* and *parvifolia* and may have arisen as a result of hybridization between the two groups. The pedicels which characterize this group link it to variety *parvifolia* but the leaf shape, size, general aspect, and depressed-conic apex of the achene link it to variety *uncinata.* The occasional presence of some uncinate hairs scattered indiscriminately on the lower surface of the leaves further shows some relationship to variety *uncinata.* Plants of this group may be identified by the pedicelled flowers and by the thick coriaceous character of

the calyx of both types of flowers and of the leaves. The leaves are very often triplinerved, and the upper surface sometimes has a rough scabrous texture, at least when dried. The venation, particularly the principal veins and primary vein branches, is very markedly raised; uncinate hairs on the venation are scattered or absent.

The range of this variety and of variety *parvifolia* nearly coincide except that variety *melastomaefolia* does not extend south of Kanehoa and variety *parvifolia* extends to Palikea and beyond. If this variety did arise by hybridization between variety *parvifolia* and variety *uncinata,* the mixing may have taken place in the Kaala region where, according to theory, a forest once existed between the two mountain ranges. The present distribution, then, would represent the distance to which the group has been distributed since its appearance. There are no real bases for such assumptions; further study, particularly of a cytological nature, may or may not uphold this hypothesis.

FIG. 3. Distribution of *Neraudia melastomaefolia* Gaud. var. *melastomaefolia* Cowan.

Neraudia melastomaefolia Gaud. variety **uncinata** Cowan, *var. nov.*

Fig. 4

Diagnosis typi: A var. *melastomaefolia* differt in foliis subtus pilis multis uncinatis in nervis secundariis, et in floribus sessilibus.

Description of all material examined: Shrub or small tree to 3 m. tall; upper branchlets usually pendent, sparsely pilosulose. Petioles 1.0–5.5 cm. long, pilosulose, few to many appressed, ascending hairs present. Leaf blades 5–15 cm. long, 2–7 cm. wide, averaging 12 cm. long, 4.5 cm. wide, narrow-elliptic to elliptic, thin, usually palmate; upper surface sparsely pilosulose, hairs few, appressed, ascending on midrib, otherwise glabrous, lower surface hairs on principal veins and primary vein branches ascending, appressed, on other vein branches hairs shorter, erect or sub-erect, uncinate, largely restricted to venation; principal veins and primary branches raised; base cuneate or cuneate and decurrent, apex long-acuminate. Pistillate flowers sessile, calyx sparsely pilosulose, only few, appressed hairs present, beak attenuate apically with four acuminate teeth at apex; stigma 4–5 mm. long, one side not receptive. Achene 1.5–2.0 mm. long, averaging about 2 mm. long, apical portion depressed-conic, separated from basal portion by only slight constriction, basal portion convex, 2–3 mm. in diameter, outer margin plane, not involute; seed ovoid, without constriction. Staminate flowers sessile, acuminately tipped lobes 3.5–4.5 mm. long, 1.5–2.0 mm. wide, averaging 4 mm. long, 2 mm. wide, pilosulose with most hairs appressed, ascending but also with few shorter, sub-erect, uncinate hairs present; pistil rudiment 0.3–2.0 mm. long; filaments 2.5–5.5 mm. long, 0.5–1.0 mm. wide; anthers 1.5–2.0 mm. long, 0.8–1.0 mm. wide.

Type: Cowan 698, Oahu, Waikane–Schofield Trail, Kahana, Koolau Range, September 20, 1947. (Deposited in Bishop Museum [Ho].)

Range: Island of Oahu, Koolau Range, moist to wet forest, 1,800–2,200 feet altitude.

Specimens examined

Data complete: Kailauloa Mts., between Punaluu and Kaipapau, Nov. 14–21, 1908, *Forbes* (Ho); Punaluu, *Rock 796, 368, 568, 626* (Ho); Punaluu Mt., trail to Castle Camp, *Rock 8838* (Gr, Ho); Waikane–Schofield Trail, *St. John 20251, 12120* (Ho), *Fosberg 8774* (Ho), *Degener 18185, 18185* (different sexes) (Ho), *Suehiro,* Oct. 16, 1932 (Ho), *Cowan 56, 57,*

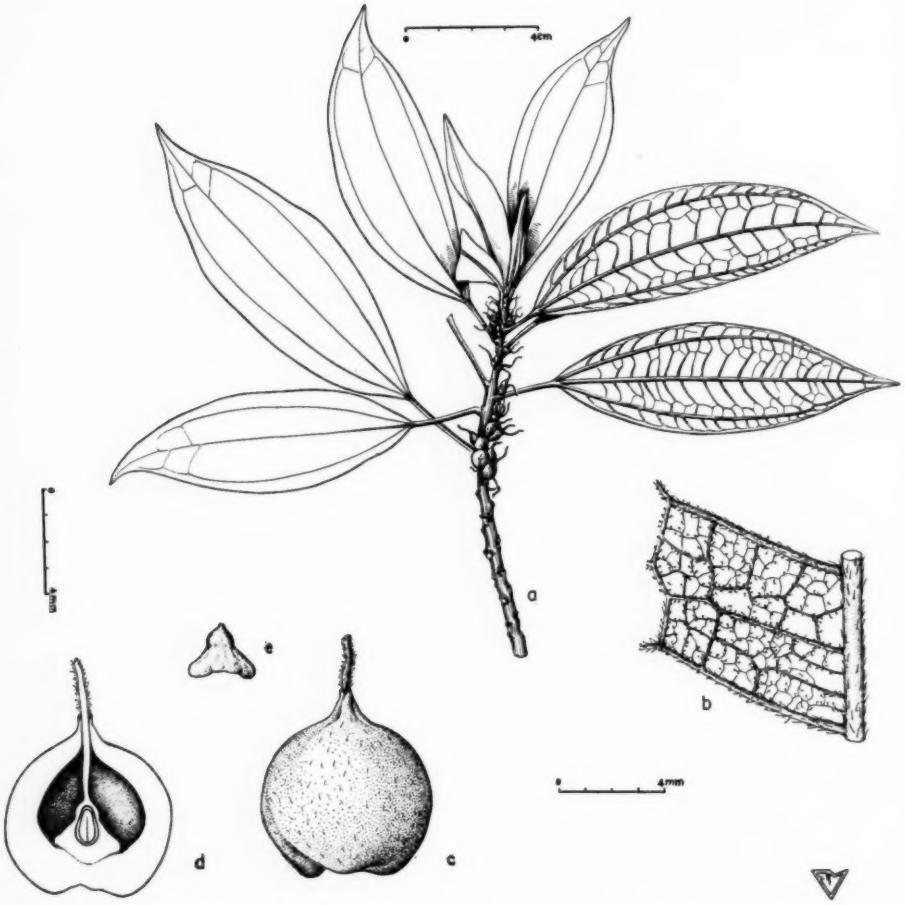

FIG. 4. *Neraudia melastomaefolia* Gaud. var. *uncinata* Cowan. *a–e,* Pistillate plant: *a,* habit (Type); *b,* portion of lower leaf surface (Type); *c,* mature calyx enclosing achene (Type); *d,* long section through mature calyx and achene (Type); *e,* external view of achene.

646, 697 (Ho), *Cowan and St. John* 7, 8 (Ho), *Baxter 120* (Ho); Waiohole Valley, *Rock,* Dec. 1919 (Ho); east side of Kaala, *Bergman* (Ho).

The last collection cited above is the only one from the Waianae Range which may be placed in this variety but it is not certain that the locality data are correct. It is intermediate in some ways but it is closest to variety *uncinata* and so is placed here rather than in variety *melastomaefolia,* to which it shows some similarity.

Judging by Wawra's geographical note on his collection of *N. melastomaefolia,* he may have collected a plant of this variety. His locality is "Waiolani" which is in the Koolau Range, the home of variety *uncinata,* and would represent the most southerly occurrence of the group.

This variety may be recognized by the many short, sub-erect or erect uncinate hairs on the secondary and smaller vein branches on the lower leaf surfaces. (The name for this variety

is taken from this diagnostic character of the leaves.) The flowers are sessile, the leaves usually palmately veined, and both leaves and calyx lobes are thin compared to variety *melastomaefolia.*

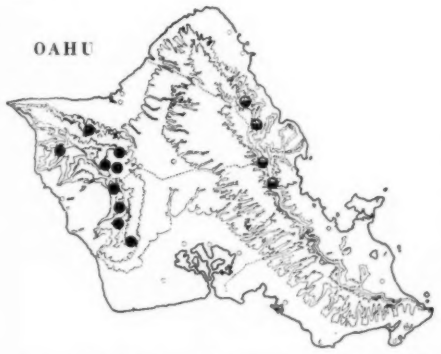

FIG. 5. Distribution of *Neraudia melastomaefolia* Gaud. var. *uncinata* Cowan (half-black dots) and var. *parvifolia* Cowan (complete black dots).

Neraudia melastomaefolia Gaud. variety **pubescens** Cowan, *var. nov.*

Fig. 6

Diagnosis typi: A var. *melastomaefolia* differt in foliis subtus adpressi vel suberecti-pilosis, achaenibus sine constrictione completa 3 mm. longis marginibus exterioribus involutis.

Description of all material examined: Tree to 6 m. tall with ascending branches, main stem to 13 cm. in diameter; upper branchlets pilosulose, hairs few to many, erect or sub-erect. Petioles 1.0–4.5 cm. long, averaging 2.5 cm. long, pilosulose, hairs few to many, appressed, sub-erect, or erect. Leaf blades 6.0–19.5 cm. long, 1.5–6.5 cm. wide, averaging 10 cm. long, 4 cm. wide, elliptic, thickish, palmate; above glabrous, below pilosulose, many appressed or sub-erect, ascending hairs present; margin entire, base cuneate and decurrent or slightly rounded and sub-obtuse, apex evenly or abruptly long-acuminate. Pistillate flowers sessile, calyx pilosulose, few to many ascending, appressed hairs present, beak attenuate apically with four acute teeth at apex; stigma 3–8 mm. long, one side often without receptive stigmatic hairs; calyx surrounding mature achene thin, fleshy-coriaceous, 7.5–13.5 mm. long and 6–10 mm. wide, averaging about 10 mm. long and 8 mm. wide when fresh but drying to 5–8 mm. long, and 3.0–5.5 mm. wide, averaging 6 mm. long and 4 mm. wide. Achene 2.5–3.5 mm. long, averaging 3 mm., apical portion conic without complete, definite, constriction at base, basal portion occupying at least half of height of achene, 3–4 mm. in diameter at base, rounded, often deeply furrowed, outer margin strongly involute; seed ovoid with acute apex. Staminate flowers sessile or rarely pedicelled, calyx pilosulose, hairs many, ascending, appressed, and occasionally with few shorter uncinate hairs, lobes navicular, 3.5–6 mm. long, 1.5–2 mm. wide, with acuminate or long-acuminate apex; pistil rudiment 0.8 mm. long; filaments 3.5–5 mm. long, 0.6–0.8 mm. wide; anthers 1.5–2 mm. long, 0.5–1 mm. wide.

Type: Heller 2792, Kauai, Kaholuamanu, above Waimea, Sept. 2–9, 1895. (Type deposited in Bishop Museum [Ho]; parts of type collection in P, G, UC, GH, NY, and Mich.)

Range: Island of Kauai, rain forest, 3,000–4,000 feet altitude.

Specimens examined

Data complete: Head of Awaawapuhi Valley, Honopu, *St. John et al. 22890, 22891* (Ho); Waimea, forests of Kokee, *Skottsberg 993* (Ho); Kokee-Nualolo Trail, *Selling 3097* (Ho); Near Kokee Stream, *Degener 18189* (NY); Halemanu, *Rock 2374* (Ho) *(2374–2386* [GH, Ho]); Kaholuamanu, *Rock 9007* (Ho); Kaholuamanu, *Rock 5327 (5326–5329)* (Ho); Kaholuamanu, *Forbes 398-K* (Ho); Haupu, 2,000 feet, *MacDaniels 887* (Ho); Waimea Drainage Basin, Kokee, West Side, *Forbes 829-K* (Ho); Waimea Drainage Basin, West Side, Kokee, side of Waimea Canyon, *Forbes 865-K* (Ho); Hii Mountains (Slopes of Puu Kahili, southwest of peak), *Forbes 667-K* (Ho).

Data not complete: Kauai, part of *Mann and Brigham 624* (Ho).

The character separating this group from variety *uncinata,* which it closely approaches

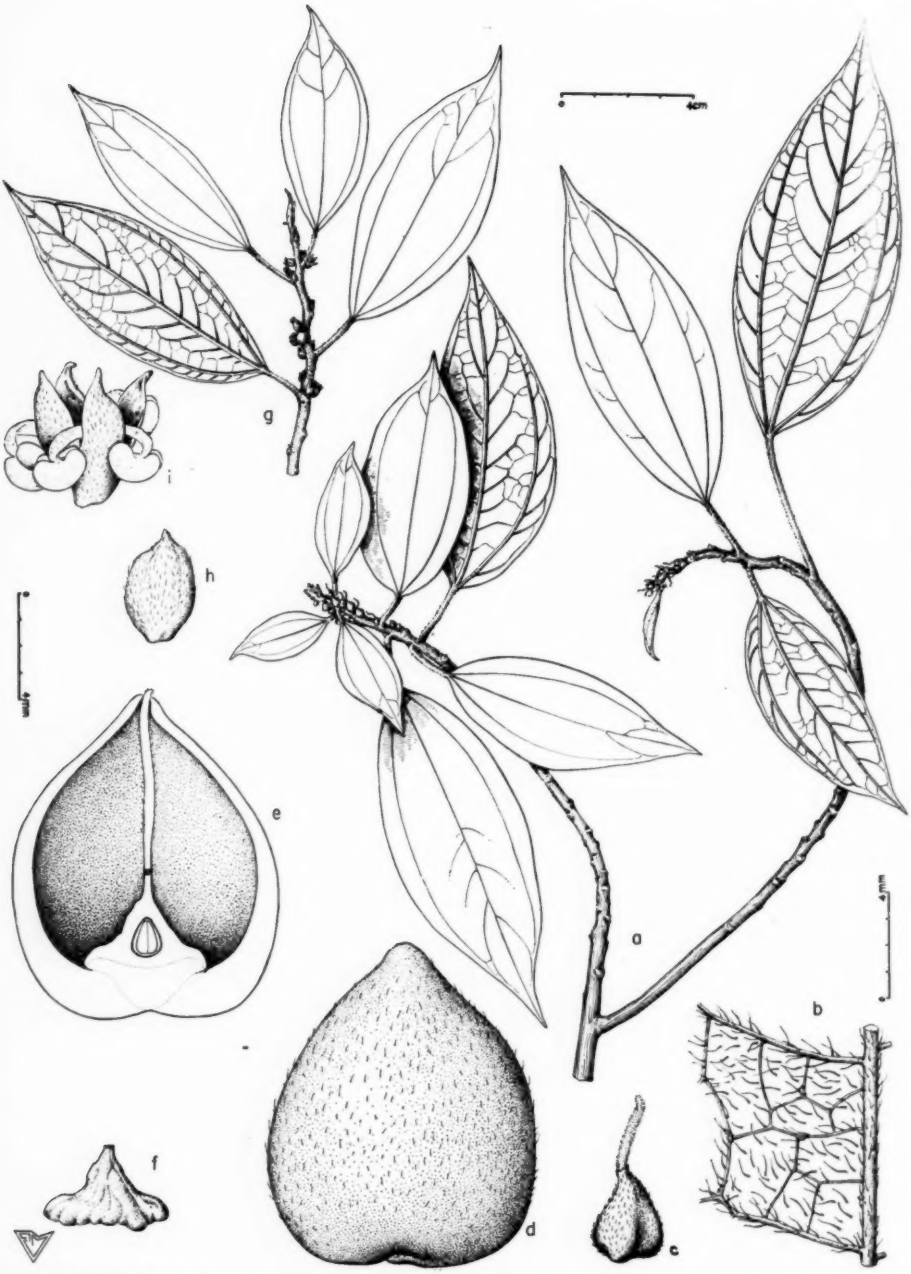

FIG. 6. *Neraudia melastomaefolia* Gaud. var. *pubescens* Cowan. *a–f*, Pistillate plant: *a*, habit (Type); *b*, portion of lower leaf surface (*Forbes 829-K*); *c*, young flower (Type); *d*, mature calyx enclosing achene (*St. John et al. 22890*); *e*, long section through mature calyx and achene (*ibid.*); *f*, external view of achene (*ibid.*). *g–i*, Staminate plant: *g*, habit (*Rock 2379*); *h*, young flower (*ibid.*); *i*, mature flower (*ibid.*).

in general appearance, is the lack of the many uncinate hairs on the venation of the lower leaf surface. It also differs from *uncinata* in that the hairs are evenly distributed over the entire lower leaf surface and are not restricted to the venation. (The varietal epithet for this entity is drawn from the pubescent condition of the lower leaf surface.) The basal portion of the achene of variety *pubescens* is also distinctive in that it is much raised, very broad, and involute at the outer margin. Also there is no complete constriction separating the apical and basal portions. The only plants of this group observed or on which there are available data were small trees 5 and 6 meters tall, erect, with stout ascending branches; plants of the other varieties of this species are normally weak, branching, or trailing shrubs of 3 meters or less in height.

The collections of this variety are quite uniform in aspect but there are a few minor exceptions which should be noted. The uncinate hairs so characteristic of variety *uncinata* are seldom seen in variety *pubescens* but in *Rock* (1916) and in his collection *Rock 5328* there are many such hairs scattered indiscriminately over the lower leaf surface. The achene, however, is uniform in size and in the involute condition of the outer margin of the basal portion in all of the collections.

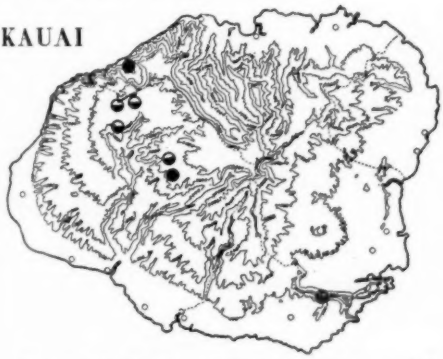

FIG. 7. Distribution of *Neraudia melastomaefolia* Gaud. var. *pubescens* Cowan (half-black dots) and *Neraudia kauaiensis* var. *kauaiensis* (complete black dots).

Neraudia melastomaefolia Gaud. variety **parvifolia** (Wawra) Hbd., Fl. Haw. Is.: 416, 1888.

Fig. 8

Nerandia sericea ? fm. *parvifolia* Wawra, Flora 57: 546, 1874.

Neraudia melastomifolia forma *truncata* Skottsberg, Horti Gotob., Acta 15(4): 351, 1944.

Low spreading shrub or half-vine 1–6 m. long; upper branchlets sparsely pilosulose, hairs few, ascending, appressed. Petioles 1–3 cm. long, pilosulose, hairs few, ascending, appressed. Leaf blades 3.0–8.5 cm. long, 1.5–5.0 cm. wide, averaging 6 cm. long, 3 cm. wide, lanceolate, elliptic-lanceolate, elliptic, elliptic-ovate, ovate, or oval, thin to sub-membranous, chartaceous, palmate; above sub-glabrous, with very few, straight, ascending, appressed hairs, below with few, straight, appressed hairs mostly restricted to veins; margin entire, base usually sub-obtuse or obtuse, sometimes slightly cordate or cuneate, apex usually abruptly acuminate or acute, only the principal veins slightly raised. Pistillate flowers on filiform pedicels 0.5–2.0 mm. long, calyx pilosulose with both straight, ascending, appressed hairs and shorter, erect, uncinate hairs, beak attenuate apically with four short, acute teeth at apex; stigma 3–5 mm. long, all sides receptive and stigmatic. Achene 1–2 mm. long, apical portion conic without constriction from basal portion (or rarely depressed-conic with constriction), basal portion flat, thin, outer margin plane, rarely revolute or involute, occasionally lobed, 2–3 mm. in diameter; seed ovoid. Staminate flowers with pedicels 0.5–2.0 mm. long, calyx with many, short, erect or sub-erect, uncinate hairs, longer, straight, appressed, ascending hairs sometimes present on margins of lobes of calyx or at extreme base, lobes 4–5 mm. long, 1.5–2.0 mm. wide, apex abruptly long-acuminate; filaments 3.0–4.5 mm. long, 0.5–1.0 mm. wide; anthers 2 mm. long, 1 mm. wide.

Lectotype: St. John 10599, Waianae Range, Puu Hapapa, Honouliuli, on ridge, 2,500 feet

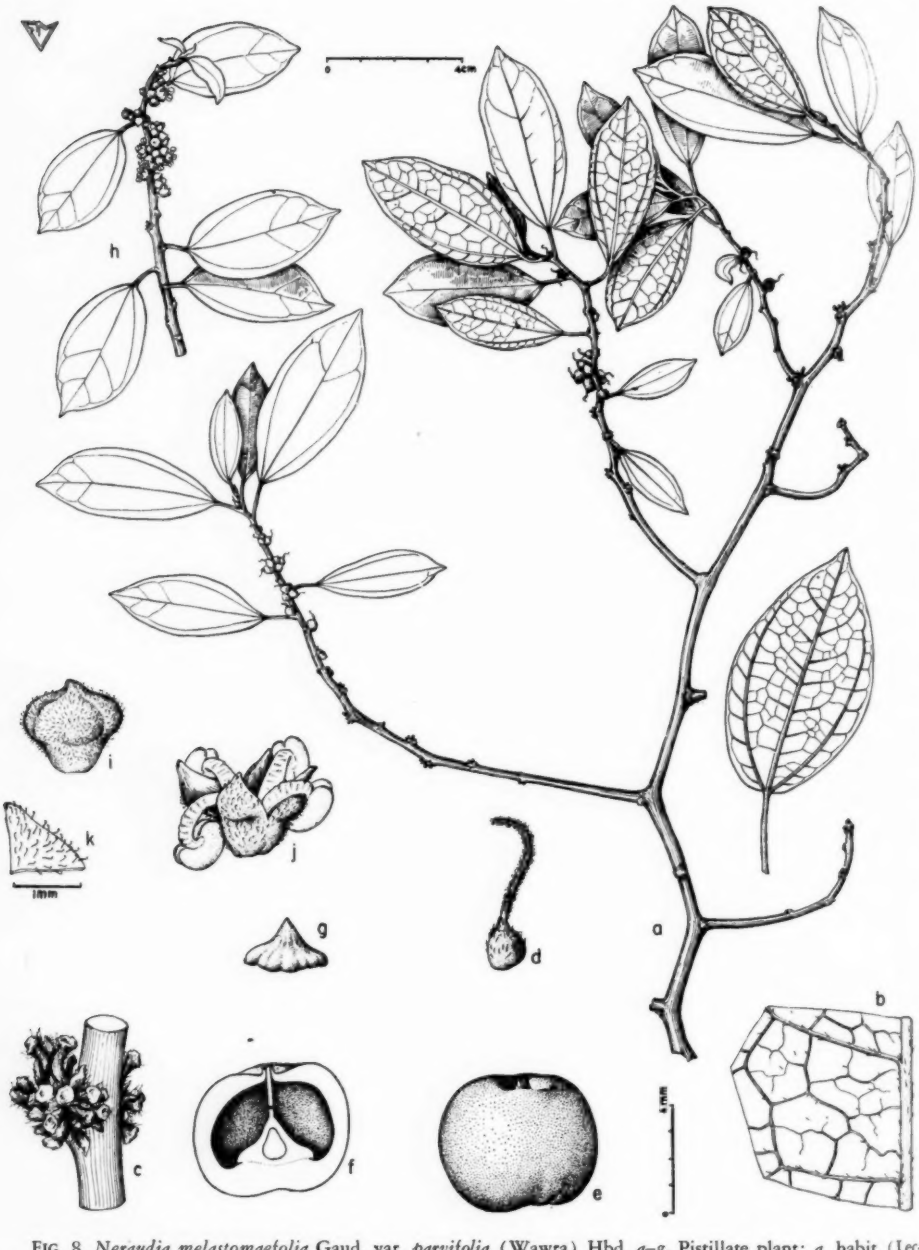

FIG. 8. *Neraudia melastomaefolia* Gaud. var. *parvifolia* (Wawra) Hbd. *a–g*, Pistillate plant: *a*, habit (Lectotype); *b*, portion of lower leaf surface (*ibid.*); *c*, one node (*ibid.*); *d*, young flower (*ibid.*); *e*, mature calyx enclosing achene (*Cowan and Sakimura 615*); *f*, long section through mature calyx and achene (*ibid.*); *g*, external view of achene (*ibid.*). *h–k*, Staminate plant: *h*, habit (*Cowan 673*); *i*, young flower (*Cowan and Sakimura 616*); *j*, mature flower (*ibid.*); *k*, portion of one lobe of calyx (*ibid.*).

altitude, Oct. 19, 1930. (Type deposited in Bishop Museum [Ho].)

Range: Island of Oahu, Waianae Range, moist forest and moist pockets of forest along the ridges, 1,600–3,500 feet elevation, Mt. Kaala to Palikea.

Specimens examined

Data complete: Makaleha Ridge, *Rock 17084* (Ho); Northeast slope of Puu Kumakalii, *Degener 17506* (NY); First large side-valley south of Makua Valley, *Degener 18183* (NY); Makaha Valley, *Forbes* (Ho); Puu Kaala, *Cowan and St. John 325, 316* (Ho); Slope of Kaala, *Selling 3669* (Ho); East ridge of Puu Kaala, *St. John 9933* (Ho); Mt. Kaala, *Nitta 37* (NY); Base of Kaala, northeast side, *Degener 18191* (NY); Mt. Kaala Trail, *MacDaniels 926* (Ho); Puu Hapapa, *St. John 10422* (Ho); Small valley southeast of Puu Hapapa, *Degener 18192* (NY); Small valley northeast of Puu Hapapa, *Degener 18189* (Ho); Southeast slope of Puu Hapapa, *Degener 12235* (Ho); South part of Puu Hapapa, *Selling 3363* (Ho); Puu Hapapa, *Meebold* (Ho); Between Puu Kanehoa and Puu Kaua, *Degener 17192, 17647* (NY); Middle ridge east of Puu Kanehoa, *Degener 12803* (NY); Kanehoa, *Frederick 206* (Ho); In gulch below Kanehoa, *Cowan 1055, 1056* (Ho); Kupehau Gulch, *Cowan and St. John 141, 147* (Ho); Along ridge trail in vicinity of Palikea, *Cowan and Sakimura 615, 616, 617* (Ho), *Cowan 663, 673, 690, 691, 803, 809* (Ho); Kaaikukae, *Russ* (Ho).

Data not complete: Hillebrand, no locality (K); Honolulu, *Hillebrand* (K); Oahu, *Forbes* (Ho); Oahu, *Remy 198* (P).

Wawra in 1874 described a forma *parvifolia* of *N. sericea* which Hillebrand raised to varietal status and transferred to *N. melastomaefolia.* The range given by Hillebrand fits very well and the description is adequate for recognition. However, the size of the leaves and petioles described by Wawra and copied by Hillebrand suggests that Wawra probably had an unusually small-leaved form. G. von Beck, in a consideration of Wawra's work, transferred Wawra's collection *(151),* originally cited under his forma *parvifolia* of *N. sericea,* to *N. melastomaefolia* but did not consider it to be any different from the "typische Form." In entirety, he says, "Alpine Form mit kleinen Blättern (4 cm. lang), sonst wie die typische Form." In 1935 St. John made a search in the herbarium at Vienna for this material but neither he nor the director was able to locate it. In spite of this, Hillebrand's interpretation of this group is accepted and the name applied.

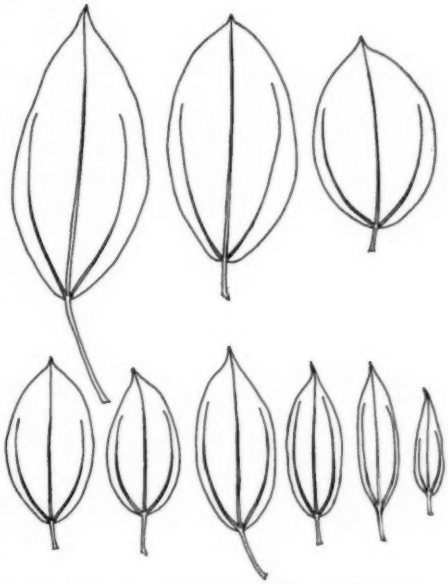

FIG. 9. Outlines of leaves to show variation in leaf shape and size in *Neraudia melastomaefolia* Gaud. var. *parvifolia* (Wawra) Hbd.

Upon first examination of the facts it seemed that Meyen's name, *N. glabra,* should be applied to this group but additional and more detailed study has revealed that Meyen's name is not applicable in this genus. In his journal, writing of his excursion into Nuuanu Valley, he says (translated), "Here we found the plant called 'mamaku' from which the Indians make their ordinary tapa; it belongs to the Urticaceae and is *Neraudia melastomaefolia* Gaud.; a new species of this genus, *Neraudia glabra* n. sp.,

grows here very plentifully and is likewise used in making the cloth." Then in a footnote he described his new species as follows: "N. foliis late ovatis acuminatis crenatis utrique glabris!" Later, in 1843, in Walpers Enumeration of the family he transferred his own species to *Boehmeria* with a slightly different description: "Foliis (oppositis an alternis ?) late ovatis acuminatis crenatis utrinque glaberrimis penninerviis." It seems from the data above that Meyen had a specimen of another genus rather similar in aspect to *Neraudia,* perhaps *Pipturus.* The Hawaiian name "mamake" is recorded by most workers for *Pipturus* and is basically the "mamaku" of Meyen. The crenate margin of the leaves is a definite characteristic of the species of *Pipturus* and the penninerved condition of the leaves which Meyen describes does not fit *Neraudia* at all. Also this group, variety *parvifolia,* occurs only in the Waianae Range. It seems obvious that Meyen's name is based upon something other than *Neraudia* and it is excluded although his material is now impossible to obtain for verification. The director of the herbarium at Vienna has notified us that the section of the herbarium containing the Urticaceae was destroyed by fire during the recent war. This same catastrophe also destroyed Wawra's material.

This group has been the most commonly collected of the genus but it is quite local in its occurrence. It is separated from variety *melastomaefolia* and variety *uncinata* by the almost completely glabrous condition of the lower leaf surface, by the usually sharply conic achene, by the predominance of short, erect, uncinate hairs on the staminate flower calices, by the typically obtuse or sub-obtuse leaf bases, and by the thin to sub-membranous leaves. It has, in common with variety *melastomaefolia,* pedicelled flowers, but it may be separated (even in the sterile condition) by the thinner leaves, the often obtuse or sub-obtuse base, and by the only slightly raised venation. The greatest difficulty in this group is that of getting actively flowering material and the result is that unless the material is in good flowering or fruiting condition it is difficult to identify with the keys. This is true because the pedicels which characterize the group are present only in a fertile or recently fertile state; Key II should assist in the identification of such collections as are in the vegetative state, without flowers, or only weakly flowering. (See Fig. 5 for distribution.)

Neraudia melastomaefolia Gaud. variety **Gaudichaudii** Cowan, *var. nov.*

Diagnosis typi: A var. *melastomaefolia* differt in foliis subtus adpressi–pilosulis, lobis calycum masculorum sine pilis uncinatis.

Description of all material examined: Shrub; upper branchlets curving, pendent, sparsely appressed pilosulose. Petioles 1–4 cm. long, sparsely pilosulose. Leaf blades 6.5–14.0 cm. long, 3.5–6.0 cm. wide, averaging 9 cm. long, 4 cm. wide, elliptic, thin to thickish, usually triplinerved; above glabrous or with very few appressed hairs, below pilosulose with many long, straight, appressed or sub-erect hairs (0.8–1.0 mm. long) scattered over entire surface; principal veins raised, primary branches less salient; base cuneate and usually markedly decurrent, apex abruptly acuminate with usually a blunt tip. Pistillate flowers sessile, calyx pilosulose with many appressed, ascending hairs, beak attenuate apically with four acuminate teeth at apex; stigma 2–5 mm. long, one side lacking receptive stigmatic hairs. Achene 1.75–2.0 mm. long, apical portion depressed conic, separated from basal portion by only slight constriction, basal portion thickened, flattened, 2.0–2.5 mm. in diameter, outer margin plane. Staminate flowers on short pedicels 0.5–1.0 mm. long, calyx pilosulose with many straight, appressed, ascending hairs, lobes navicular, 3–4 mm. long, 1.0–1.5 mm. wide; filaments 3.5–4.0 mm. long, 0.4–0.5 mm. wide; anther sacs 1.5–2.0 mm. long, 0.75–1.0 mm. wide.

Type: Selling 3697, Oahu: Koolau Mts., Punaluu. September 27, 1938. (Type deposited in Bishop Museum [Ho].)

Range: Oahu, Punaluu region of Koolau Range in upper rain forest.

Specimens examined: Pig-God Trail, Punaluu, *Degener 18184* (NY), *17117* (NY); Punaluu, *Webster 1603* (U. of Tex.).

This variety is similar in appearance to variety *uncinata* but differs in its complete lack of uncinate hairs on any plant part, by its staminate flowers borne on pedicels, and by the presence of many rather long hairs scattered over the entire lower leaf surface. In this latter character it resembles variety *pubescens* but differs in its smaller calices, by the depressed-conic apical portion of the achene, and by its usually triplinerved leaves. It is remarkably similar to variety *melastomaefolia* but the long hairs all over the lower leaf surface and the lack of uncinate hairs on any plant part separate it from this variety. Variety *Gaudichaudii* appears to be most closely related to variety *melastomaefolia.*

This variety is named in honor of Charles Gaudichaud, one of the most illustrious botanical travelers of the early exploratory period of the Hawaiian Islands. He described many genera from these islands and the genus *Neraudia* was one of them. He is also the author of three of the species assigned to the genus.

Neraudia melastomaefolia Gaud. variety **pallida** Cowan, *var. nov.*

Diagnosis typi: A var. *melastomaefolia* differt in foliis subtus glabris, pallidissimis, floribus sessilibus, rostro calycis ad apicem plerumque expanso.

Description of all material examined: Upper branchlets sub-glabrous with few, straight, ascending, appressed hairs. Petioles 1–3 cm. long, glabrous or sparsely pilosulose with few, ascending, appressed hairs. Leaf blades 6.0–7.5 cm. long, 1.5–3.0 cm. wide, elliptic, oblance-elliptic, or somewhat obovate, thin, palmate; upper surface with very few, ascending, appressed hairs, under surface glabrous or with few hairs on venation; margin entire, base narrowing, cuneate or sub-obtuse, apex abruptly or evenly acuminate or long-acuminate. Pistillate flowers sessile, calyx with few ascending, appressed hairs, beak expanding apically or sometimes attenuate, four-toothed; stigma 4–7 mm. long and receptive on all surfaces or stigmatic hairs sometimes absent from one side. Achene (mature ?) about 1 mm. long, apical portion hemispherical or elongate-hemispherical without constriction from basal portion, outer margin of basal portion plane, about 2 mm. in diameter; seed ellipsoid. No staminate flowers available.

Type: Forbes 2365-M, ridge upper part of Olowalu Valley, Maui, May 14, 1920. (Type deposited in Bishop Museum [Ho].)

Range: Island of Maui, western part.

Specimen examined: Forbes 2470-M, up Olowalu Valley and up right-hand side on ridge, May 23, 1920 (Ho).

The material representing this group is so scanty that its evaluation and proper position in relation to other groups are not entirely clear. The group is recognizable and therefore is named in order to call it to the attention of future collectors. It may be separated by the very pallid appearance of the lower leaf surface when dry and the usually expanded beak of the pistillate calyx. (See Fig. 20 for distribution.)

Neraudia angulata Cowan, *sp. nov.*

Diagnosis: Frutex 1.5–3.0 m. altus; petiolis 0.8–3.0 cm. longis, perbreviter pilosis, laminibus 6.5–13.0 cm. longis, 3.5–5.0 cm. latis, ellipticis vel elliptico-ovatis vel ovatis tenuibus supra adpressi-pilosulosis infra valde curvati- vel adpressi-pilosulosis sericeis marginibus integris vel partim dentatis vel dentatis ad basim cuneatis vel sub-obtusis vel obtusis ad apicem gradatim vel abrupte longi-acuminatis aliquando triplinervatis. Floribus femineis sessilibus, calycibus angulatis valde adpressi-pilosulosis et erecti-pilosulosis, rostro calycis ad apicem contracto acute 4-dentato, stigmate 2–8 mm. longo uno latere sine pilis receptivis. Achaeneis 1.5–2.0 mm. longis, parte apiculo conico ad basim sine constrictione, parte basali crasso 1.5–2.0 mm. diametro marginibus exterioribus in sicco nonnihil involutis et angulatis,

in calyce carnoso 0.75–1.25 mm. crasso subalato angulatoque inclusis; semene ovato. Floribus masculis sessilibus vel rare pedicellatis, calycibus valde pilosulosis, lobis 2.0–3.5 mm. longis 1.0–1.5 mm. latis anguste navicularibus ad apicem longi-acuminatis, filamentis 4 mm. longis, 0.75 mm. latis, anteris reniformibus 1.5 mm. longis 0.75 mm. latis.

Description of all material examined: Erect shrub 1.5–3.0 m. tall, 1–4 cm. in diameter at base of main stem, upper branchlets with many erect and appressed, or only erect, hairs. Petioles 0.8–3.0 cm. long, with many appressed and erect hairs. Leaf blades 6.5–13.0 cm. long, 3.0–5.5 cm. wide, elliptic-ovate, ovate, or oval, thin, palmate or triplinerved; above sparsely sericeous, hairs ascending, below sericeous with more or less dense layer of strictly appressed or sub-erect hairs, oriented centripetally within primary intervals and mostly directed toward margin, pilosulose on raised principal veins, hairs appressed or sub-appressed; margin entire, repand, partly dentate or completely dentate, base cuneate-decurrent to obtuse and rotund, apex evenly or abruptly long-acuminate or only acute. Pistillate flowers sessile, calyx sericeous, hairs appressed to erect intermixed with some shorter, erect, uncinate hairs, calyx beak attenuate apically with four sub-acuminate to long-acuminate teeth at apex; stigma 2–8 mm. long, without receptive stigmatic hairs on one surface. Achene 1.5–2.0 mm. long, angled, apical portion conic, not separated from basal portion by constriction, basal portion flat-convex, 1.5–3.0 mm. in diameter, outer margin drying involute; seed ovoid. Staminate flowers sessile or with pedicels 1 mm. or less long, calyx sericeous, hairs ascending, lobes navicular, 2.0–3.5 mm. long, 1.0–1.75 mm. wide, apex long-acuminate; filaments 3–4 mm. long, 0.3–0.5 mm. wide; anther sacs 1.5–2.0 mm. long, 0.5–1.0 mm. wide.

This species is separated from all others by the sericeous condition of the plants, particularly of the lower leaf surface and by the conspicuously angled and ridged, fleshy calyx surrounding the mature achene. The two varieties comprising the species are separated on the basis of the posture of the hair on the lower leaf surface and on the leaf margin. The name for the species is taken from the angled character of the mature pistillate calyx.

This is the group to which Hillebrand applied Gaudichaud's name, *Neraudia sericea,* when he reduced it to a variety of *N. melastomaefolia.* A fragment of Hillebrand's material, which upon examination proves to be what is named here *N. angulata,* is in the herbarium of Bishop Museum.

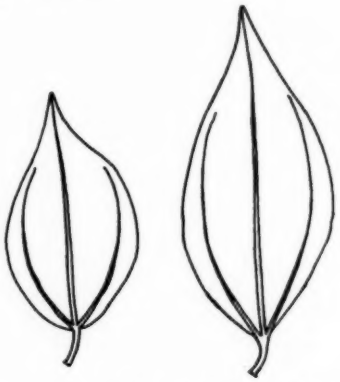

FIG. 10. Leaf outlines to show variation in leaf shape and shape of leaf base in *Neraudia angulata* Cowan var. *angulata* Cowan.

Neraudia angulata Cowan variety **angulata** Cowan, *var. nov.*

Diagnosis typi: A var. *dentata* differt in foliis marginibus semper integris subtus valde adpressi-pilosulosis sericeis.

Description of all material examined: Shrub 2.0–2.5 m. tall. Petioles 1–5 cm. long. Leaf blades 7–13 cm. long, 3.5–5.0 cm. wide, averaging 8 cm. long, 4 cm. wide, elliptic or elliptic-ovate, margin entire, base cuneate-decurrent, apex long-acuminate; below sericeous with more or less dense covering of appressed hairs, centripetally oriented in primary intervals and somewhat marginally directed, producing a conspicuous geometrically uneven sheen on lower leaf surface.

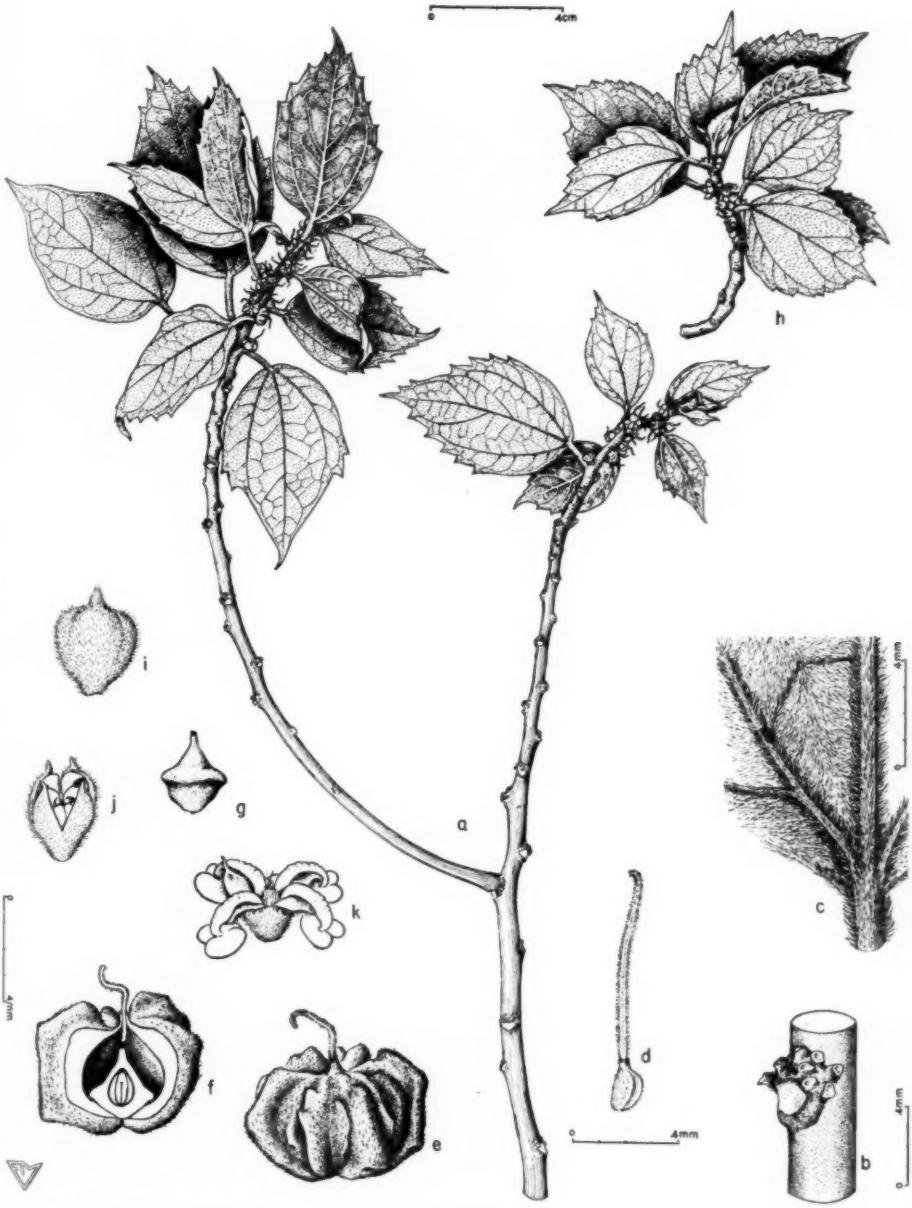

FIG. 11. *Neraudia angulata* Cowan var. *dentata* Degener and Cowan. *a–g*, Pistillate plant: *a*, habit (Type); *b*, one node (Type); *c*, portion of lower leaf surface (Type); *d*, young flower (Type); *e*, mature calyx enclosing achene (Type); *f*, long section through mature calyx and achene (Type); *g*, external view of achene (Type). *h–k*, Staminate plant: *h*, habit (*Cowan 761*); *i*, young flower *(ibid.)*; *j*, opening flower *(ibid.)*; *k*, mature flower *(ibid.)*.

Type: Forbes 1828-O, Mokuleia, slopes of Kaala, April 26–May 16, 1912. (Type deposited in Bishop Museum [Ho].)

Range: Island of Oahu, Waianae Range, in dry situations 1,900–2,500 feet altitude.

Specimens examined

Data complete: West face of Puu Kalena, Waianae Kai, *Fosberg 9264* (Ho); West branch of Waianae Valley at pali near Kolekole Pass, *Degener 18182* (NY); Puu Kaua, on easterly ridge, *Cowan 840* (Ho).

Data not complete: Honolulu, *Hillebrand* (K); *Hillebrand,* no locality (K); *Remy 196,* Hawaii (almost certainly incorrect locality) (P).

This typical variety may be distinguished from *dentata* by the entire leaf margin and the strictly or mostly appressed hair on the lower leaf surface. Rarely, *dentata* has an entire margin and then it is only the posture of the pubescence which must serve to identify it.

Neraudia angulata Cowan variety **dentata** Degener and Cowan, *var. nov.*

Fig. 11

Diagnosis typi: A var. *angulata* differt in foliis marginibus dentatis subtus valde curvati-pilosulosis sericeis.

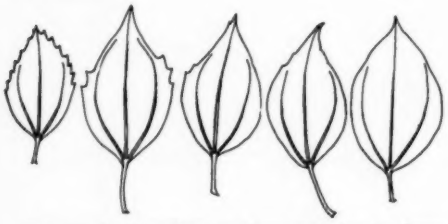

FIG. 12. Leaf outlines to show variation in dentation of leaves in *Neraudia angulata* Cowan var. *dentata* Degener and Cowan.

Description of all material examined: Shrub 1–3 m. tall. Petioles 0.8–3.0 cm. long; leaf blades elliptic, elliptic-ovate, or ovate, margin dentate, partly dentate, repand, or rarely entire, base cuneate-decurrent to obtuse, apex abruptly or evenly long-acuminate or only acute; below densely sericeous, hairs sub-erect or erect, geometrically uneven sheen on lower leaf surface not so conspicuous as in preceding, owing to more nearly erect hairs, most hairs curving toward margin apically.

Type: Cowan 750, Extension of fire-break trail, west of Puu Iki, Waianae Range, Oahu, December 7, 1947. (Type deposited in Bishop Museum [Ho].)

FIG. 13. Distribution of *Neraudia angulata* Cowan var. *angulata* Cowan (half-black dots) and var. *dentata* Degener and Cowan (complete black dots).

Range: Island of Oahu, Waianae Range, dry areas, 1,200–2,100 feet altitude.

Specimens examined

Data complete: Kaena Uplands, *MacCaughey* (Ho); Kamananui, second valley east of Puu Iki, *Russ* (Ho); Extension of fire-break trail, west of Puu Iki, above Mokuleia, *Cowan, Webster, and Wilbur 751–763* (Ho), *Degener 19181* (NY); Lualualei, central section below Kanehoa, foot of cliffs, head of valley 3, *Christophersen 3682, 3685, 3686* (Ho); Lateral easterly ridge, ¼ mile north of Puu Kaua, *Cowan 836, 837, 839, 849* (Ho).

The extent of dentation of the leaves of this variety varies considerably but usually leaves with some teeth can be found on each plant. When a collection is discovered with no dentation it is necessary to observe the posture of the pubescence on the lower leaf surface. In this variety the pubescence is sub-erect or erect and the upper part of each hair is usually curved toward the margin.

Otto Degener recently collected some material of this variety and pointed out its dis-

tinctness to me. He then kindly directed me to his locality where fourteen collections were made of plants of both sexes. Although the group had been recognized previously, the material available for its study was quite inadequate so that Mr. Degener's assistance was a very definite contribution and is gratefully acknowledged.

Neraudia kauaiensis (Hbd.) Cowan, *comb. nov.*

Neraudia melastomaefolia Gaud. var. *Kauaiensis* Hbd., Fl. Haw. Is.: 416, 1888.

Upper branchlets grayish at tip with very many straight, erect, or sub-erect hairs. Petioles 1–7 cm. long, with very many straight, erect hairs. Leaf blades 6–12 cm. long, 3.5–7.0 cm. wide, elliptic, elliptic-ovate or broadly ovate, thin, palmate, above with few to many sub-appressed to erect hairs, tuft of hairs at junction of principal veins on upper surface erect, below with very many, more or less erect, irregularly curving and bending or almost straight hairs in intervals; veins densely covered with straight, erect hairs; margin entire or irregularly undulate, base rotund or narrowing, sub-cordate, obtuse, or sub-obtuse, apex abruptly acuminate or long-acuminate. Pistillate flowers sessile, calyx densely pilosulose, hairs many, erect or sub-erect, ascending, beak attenuate apically with four short, acute or acuminate teeth at apex; stigma about 6 mm. long, receptive on all surfaces. Achene about 2 mm. long, apical portion conic, no constriction between apical and basal portions, basal portion flattened, thin, about 2 mm. in diameter, outer margin plane. Staminate flowers sessile, short-pedicelled, or with pedicels up to 2.5 mm. long, calyx with many sub-erect, ascending hairs, lobes navicular, 3–4 mm. long, 1–2 mm. wide, with long-acuminate apex; pistil rudiment less than 1 mm. long, filaments flat, strap-shaped, 2.8–4.5 mm. long, 0.2–0.5 mm. wide; anther sacs reniform, 0.8–2.0 mm. long, 0.4–1.0 mm. wide.

This species is easily separable from all other groups in the genus, except *N. sericea,* on the basis of the pubescence of the lower leaf surface. The leaves of *N. kauaiensis* usually have a sub-cordate base (except in variety *Helleri* which has irregularly undulate leaf margins) as compared to the usual cuneate base of *N. sericea.* The pubescence on the calices of flowers of both sexes in *N. sericea* is appressed, ascending, whereas the pubescence on the calices in *N. kauaiensis* is erect or sub-erect, ascending. The venation of the leaves of the two groups is different and the achene of *N. sericea* has a deep, usually acute constriction whereas the achene of *N. kauaiensis* has no such constriction.

Neraudia kauaiensis (Hbd.) Cowan variety **kauaiensis** Cowan, *var. nov.*

Fig. 14

Description of all material examined: Petioles 1–6 cm. long, averaging 2 cm. long. Leaf blades 6–11 cm. long, 3.5–7.0 cm. wide, averaging 7 cm. long, 4.5 cm. wide, elliptic-ovate or more often broadly ovate; above sparsely pilosulose, few to many sub-appressed to erect hairs present; margin entire, base rotund, sub-cordate or obtuse. Pistillate flowers sessile. Achenes as in specific description. Staminate flowers sessile or short-pedicelled, calyx lobes 4 mm. long, 1 mm. wide with acuminate apex; filaments 2.8–4.5 mm. long, 0.2–0.5 mm. wide; anther sacs 0.8–2.0 mm. long, 0.4–0.7 mm. wide.

Type: Rock 5323 (Ho) (*5322–5331* [Ho, GH]), Kaholuamanu, Kauai. (Type deposited in Bishop Museum [Ho]; portions of this collection series in GH.)

Range: Island of Kauai, wet forests.

Specimens examined

Data complete: On Kaholuamanu, above Waimea, *Heller 2881* (UC, Ho, G, P, NY, Mich.); Kaholuamanu, *Rock 17111* (Ho); Waimea Drainage Basin, West Side (Kokee region—from Forbes' field book), *Forbes 1079-K* (Ho); Kalalau Valley, *Forbes 52-K* (Ho).

Data not complete: Rock 5922 (Ho); *Mann and Brigham 624* (in part—due to the group-

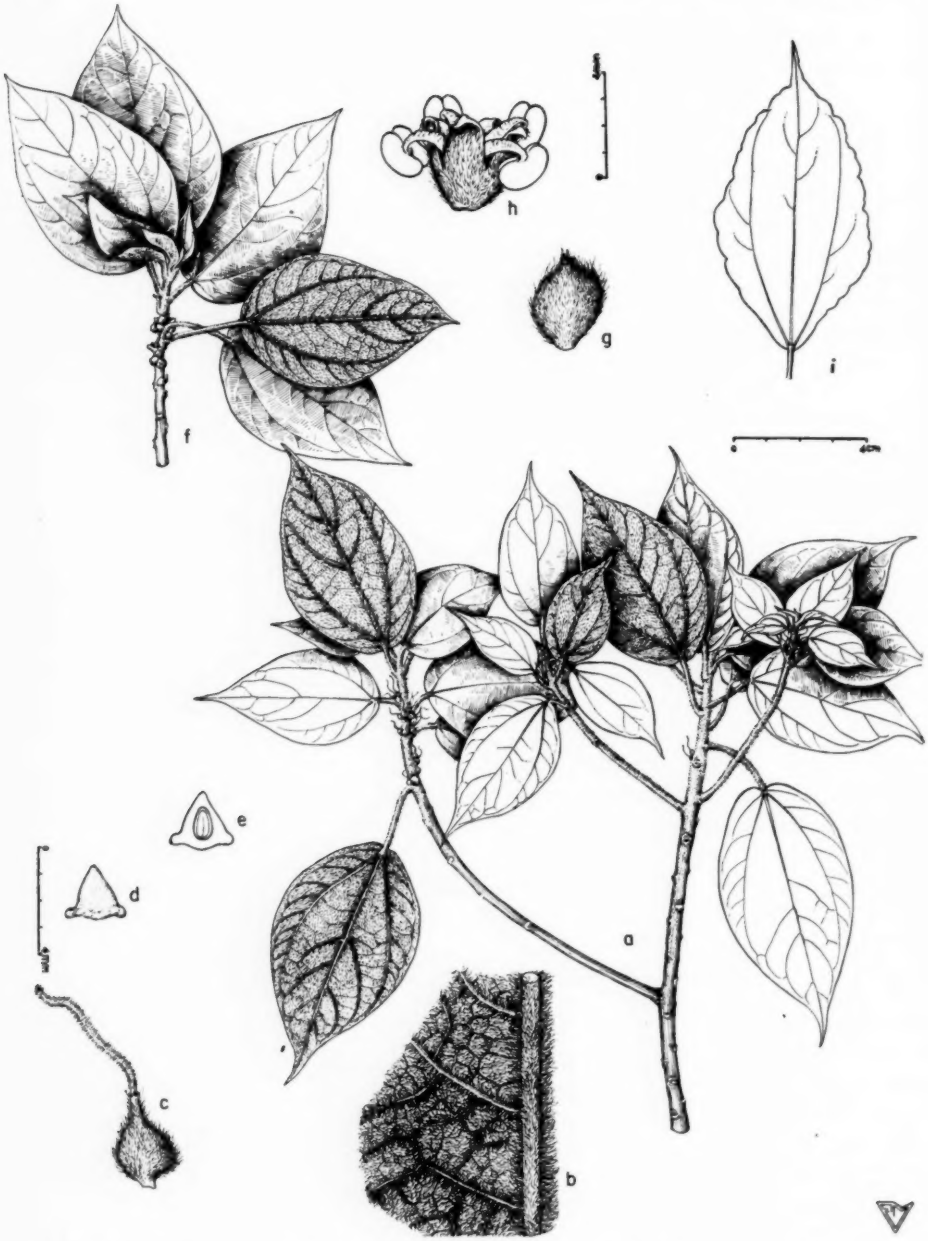

FIG. 14. *Neraudia kauaiensis* (Hbd.) Cowan var. *kauaiensis* Cowan (*a–b*); var. *Helleri* (*i*). *a–e*, Pistillate plant: *a*, habit (Type); *b*, portion of lower leaf surface (Type); *c*, young flower (Type); *d*, external view of achene (Type); *e*, long section through achene (Type). *f–h*, Staminate plant: *f*, habit (*Rock 5331*); *g*, young flower (*ibid.*); *h*, mature flower (*Heller 2881*). *i*, Outline of leaf of var. *Helleri* (Type).

ing of several collections under one number) (GH, G).

This typical variety differs from variety *Helleri* principally in its entire leaf margins. The different leaf shape and the long-pedicelled staminate flowers of variety *Helleri* serve to separate the two varieties.

Neraudia kauaiensis (Hbd.) Cowan variety **Helleri** Cowan, *var. nov.*

Diagnosis typi: A var.*kauaiensi* differt in marginibus foliorum undulatis, petiolis longioribus, pedicellisque longioribus.

Description of all material examined: Petioles 3–7 cm. long, averaging 5 cm. long. Leaf blades 6.5–12.0 cm. long, 3.5–5.5 cm. wide, averaging 8 cm. long, 4 cm. wide, elliptic to elliptic-ovate; above with many very short, appressed or sub-erect hairs; margin irregularly undulate, base obtuse or sub-obtuse. Pistillate flowers unknown. Staminate flowers with pedicels 0.5–2.5 mm. long, averaging 2 mm. long, calyx lobes 3.0–3.5 mm. long, 1.5–2.0 mm. wide; filaments 3–4 mm. long, 0.5 mm. wide; anthers 1.5–2.0 mm. long, 0.8–1.0 mm. wide.

Type: Heller 2847 (NY), "On Kaholuamanoa, above Waimea, October 1–8, 1895," Kauai (NY, P, GH, G). (Type deposited at New York Botanical Garden; also sheets at P, GH, and G.)

Range: Known from the type locality only.

Specimens examined: Only type collection available for study.

Although the material for this group is inadequate, it seems to be a distinct entity to which a name should be applied. It may be distinguished from variety *kauaiensis* by its irregularly undulate leaves and the presence of many long filiform pedicels at each node. No pistillate material is available but it is hoped that future collections in this locality may reveal the nature of the pistillate plants.

The name for this group was chosen in recognition of the outstanding field work accomplished by A. A. Heller in the Hawaiian Islands in 1895. His very acute powers of observation and awareness of plant differences resulted in the description of many new species and in a collection of much valuable material.

Neraudia ovata Gaud., Freyc. Voy.Uranie Bot.: 501, 1830.

Fig. 15

Neraudia pyrifolia Gaud., Freyc. Voy. Uranie Bot.: 94, 1826 (nomen nudum).

Boehmeria ovata (Gaud.) Endl., Wien Mus. Naturgesch., Ann. 1: 165, 1837.

Boehmeria ovata (Gaud.) Steudel, Nom. Bot. 2: 192, 1841.

Neraudia melastomaefolia Gaud. var.-β Wedd., Mus. Hist. Nat. Paris, Nouv. Arch. 9: 438–439, 1856–57.

Description of Gaudichaud's material: Upper branchlets with many short, straight, erect hairs. Petioles 1–2 cm. long. Leaves 5–6 cm. long, 3–4 cm. wide, ovate or oval, thin, palmate; above with few, very short, ascending, appressed hairs, below puberulent with many very fine, more or less erect, very short, straight or slightly bending hairs; margin entire, base obtuse or cuneate, apex contracted abruptly into an acuminate or long-acuminate tip. Pistillate flowers sessile, calyx pilosulose, hairs many, short, ascending, appressed, and with few erect, uncinate hairs intermixed, beak expanded or attenuate apically. Achene about 2 mm. long, apical portion depressed-conic, separated from basal portion by obtuse constriction, basal portion raised, involute at outer margin, about 2.5 mm. in diameter. No staminate flowers available.

Description of all material examined: Vining, sprawling, rarely erect shrub 1–3 m. tall with a spread of 3–7 m., sometimes clambering over adjacent vegetation, main stem up to 5 cm. in diameter at base; upper branchlets pilosulose, with many short, erect hairs. Leaf blades 3–10 cm. long, 2–6.5 cm. wide, elliptic, elliptic-ovate, ovate, broadly ovate, or oval, thin, palmate; above sparsely puberulent, below more densely puberulent; margin entire, base usually obtuse or sub-obtuse, sometimes cuneate, apex abruptly or evenly acuminate or long-acuminate, occasion-

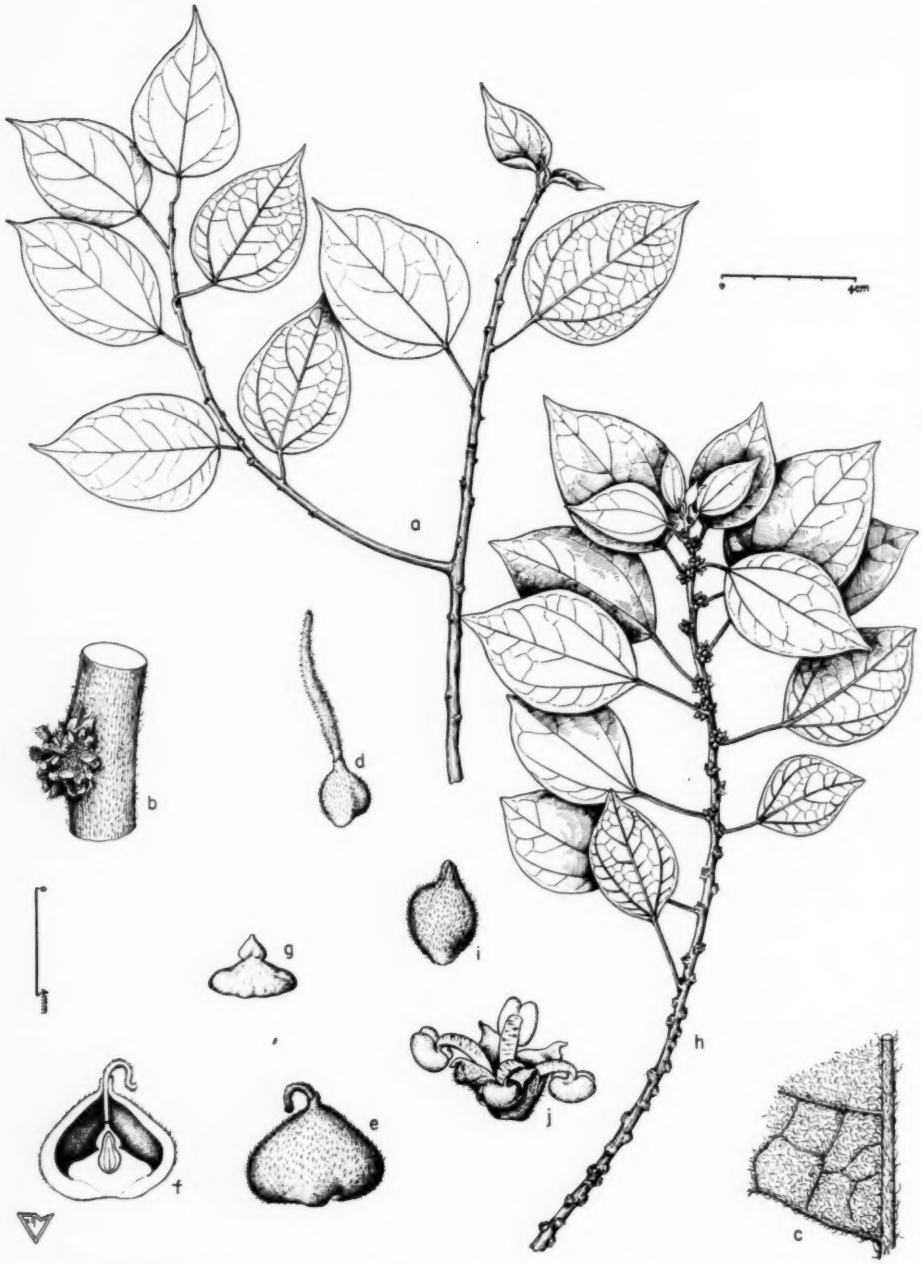

FIG. 15. *Neraudia ovata* Gaud. *a–g*, Pistillate plant: *a*, habit (Type); *b*, one node (Type); *c*, portion of lower leaf surface (*Cowan et al. 481*); *d*, young flower (*ibid.*); *e*, mature calyx enclosing achene (*ibid.*); *f*, long section through mature calyx and achene (*ibid*); *g*, external view of achene (*ibid.*). *h–j*, Staminate plant: *h*, habit (*Cowan et al. 477*); *i*, young flower (*Cowan et al. 486*); *j*, mature flower (*ibid.*).

ally only acute. Pistillate flowers sessile, calyx pilosulose, with dense covering of appressed to sub-erect hairs and shorter, erect, uncinate hairs, beak expanded or attenuate apically, four-toothed or three-toothed and collar-form; stigma 4–7 mm. long, receptive on all surfaces. Achene 2–3 mm. long, apical portion depressed conic, separated from basal portion by complete, obtuse, or acute constriction, basal portion raised and sometimes somewhat lobed, about 3 mm. in diameter, outer margin involute; seed ovoid with lateral, transverse constriction. Staminate flowers sessile or on pedicels 1 mm. or less in length, calyx pilosulose with dense covering of appressed and erect hairs, with shorter, erect, uncinate hairs intermixed, lobes membranous, with long-acuminate apex, 3.0–4.5 mm. long, 1.0–1.5 mm. wide; pistil rudiment 0.3–1.0 mm. long, filaments 3–5 mm. long, 0.5–0.75 mm. wide, anther sacs 1–2 mm. long, 0.5–1.0 mm. wide.

Type: Gaudichaud, "In insulis Sandwicensibus." (Type deposited in Museum National d'Histoire Naturelle de Paris [P].)

Range: Island of Hawaii, dry parts of lava fields 1,000–3,000 feet altitude.

Specimens examined

Data complete: Peter Lee Road near Half-Way House, *Fagerlund and Mitchell 842* (Ho); Kau, *Rock 8776* (Ho, GH); Kapua, *MacDaniels* (Ho); Kanahaha, Kona, *Forbes 361-H* (Ho); Puuwaawaa, *Forbes 28-H* (Ho); North Kona, below Lind's Place and Puuwaawaa branch road, *Skottsberg 1956* (Ho); Puuwaawaa, *Degener 18187* (NY); North Kona, Puuwaawaa, *Skottsberg 673* (Ho); Puuwaawaa, ¾ mile west of Puu Anahulu, *Cowan 483–486* (Ho); Puuwaawaa, North Kona, *Fagerlund and Mitchell 1019* (Ho); Huehue, North Kona, *Rock 4015* (Ho) (*4013–4017* [GH, Ho]); North Kona, vicinity of Huehue near main road, *Selling 3203* (Ho); Huehue, North Kona, *Frederick* (Ho); North Kona, near Lind's Place, *Skottsberg 1962* (Ho); Huehue, *Meebold* (Ho); Near Huehue Ranch, Kaupulehu, *Cowan et al. 477–482* (Ho).

The leaf shape in this species is variable and though it is not always ovate as Gaudichaud supposed, there is a tendency in that direction. The material on which Gaudichaud based his description shows leaves which are predominantly broadly ovate but the many later collections show the inconstancy of this character. In several of the collections a few or all the leaves are elliptic but the extreme of this condition is reached in *Cowan et al. 485* in which the leaves are narrow elliptic with a long-acuminate apex and cuneate base and the petioles average longer than in the remainder of the material. A group of some status might be segregated on these differences but I have not been convinced of the justification of such a segregation.

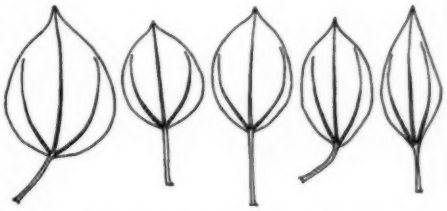

FIG. 16. Leaf outlines to show variation in leaf shape in *Neraudia ovata* Gaud.

The shape and size of the achene are generally constant, at least in the involution of the outer margin of the basal portion. However, in *Forbes 28-H* and *361-H* the outer margin is thin and plane instead of strongly involute as is typical.

This species is unlike any other group in the genus in its vining or clambering habit. From limited observations, it seems that the plants remain more or less erect shrubs with lax, arcuate, branches until of considerable size. That the vine-like habit is characteristic is indicated by several very large (up to 7 m. long) plants which were observed to be clambering over and into adjacent *Metrosideros* trees. Ten collections of the group were made on Hawaii during December, 1946. The plants were found growing in dry soil or out of

crevices between boulders of rough lava. Several seedlings were collected from beneath one pistillate plant and one of these was successfully grown for 18 months in the cool, humid conditions of Manoa Valley on Oahu. This fact would seem to indicate that the plant is capable of considerable adjustment, for the conditions under which it grew on Oahu are nearly the opposite of those in the original locality. The puberulent character of the leaves and their shape remained typical after a year and a half of cultivation. It flowered twice, producing pistillate flowers. Pollination with pollen from an Oahu plant (of another species) was attempted without success. This observation may indicate that genetic barriers exist between some of the groups.

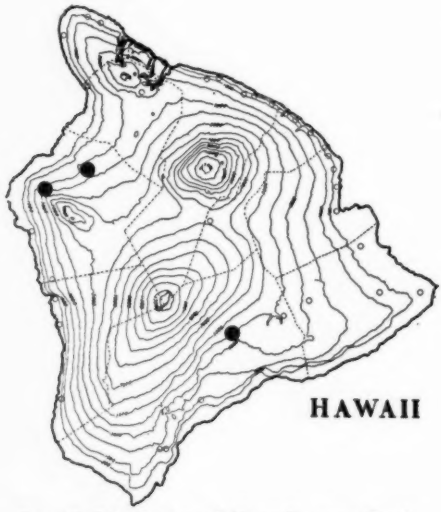

FIG. 17. Distribution of *Neraudia ovata* Gaud.

Neraudia sericea Gaud., Bot. Voy. Bonite: pl. 133, 1851.

Fig. 18

Description of Gaudichaud's material: Upper branchlets pilosulose, hairs many, erect, or suberect, ascending. Petioles 1–3 cm. long, pilosulose, hairs many, irregularly bending. Leaf blades 7.0–9.5 cm. long, 4.0–6.5 cm. wide, broadly oval or ovate, rather thickish, triplinerved or palmate; above with few ascending, appressed hairs and tuft of hair at point of divergence of principal veins also appressed, ascending, below densely pilosulose, hairs irregularly bending and curving, grayish or whitish, rather shiny, 0.8 mm. or more long; on upper surface of venation hairs ascending, appressed, on lateral surfaces hairs divergent; margin entire, base cuneate or sub-obtuse, apex contracted abruptly or tapering evenly into an acute to long-acuminate tip, principal veins raised on lower leaf surface. Pistillate flowers sessile, calyx pilosulose with many straight, ascending, appressed hairs; stigma with one side lacking stigmatic hairs. No mature achenes or staminate flowers available.

Description of all material examined: Upper branchlets with very many short, erect or suberect hairs. Petioles 0.8–5.0 cm. long, averaging 3 cm. long, with many erect to sub-erect hairs. Leaf blades 3.5–8.5 cm. long, 2–5 cm. wide, averaging 7 cm. long, 4 cm. wide, thin to thickish, narrowly elliptic, elliptic-ovate, ovate, slightly obovate, oval, or broadly oval, mostly triplinerved; above pilosulose with many ascending, appressed hairs, tuft of hairs at junction of principal veins on upper surface appressed, ascending, below densely pilosulose, hairs irregularly bending and curving, grayish or whitish, pilosulose on principal veins and primary branches, hairs appressed, ascending, lateral surfaces of veins with or without fringe of hairs oriented at approximately 90° to the veins; margin entire or rarely a few teeth present on very young leaves, base cuneate, rarely subobtuse or obtuse, apex abruptly or sometimes evenly long-acuminate, acuminate, or acute. Pistillate flowers sessile, calyx pilosulose with many straight, appressed, ascending hairs and few shorter, erect, uncinate hairs, beak expanded apically or rarely attenuated to four-toothed, entire, or laciniate apex; stigma 3–5 mm. long, all sides receptive. Achene 1.5–2.0 mm. long, apical portion depressed-conic, separated from basal portion by deep, acute or obtuse constriction, basal portion flat-convex, 2.5–3.0 mm.

FIG. 18. *Neraudia sericea* Gaud. *a–e*, Pistillate plant: *a*, habit (*Rock*); *b*, portion of lower leaf surface (*Rock*); *c*, young flower (Type); *d*, external view of achene (*Rock*); *e*, long section through achene (*Rock*). *f–h*, Staminate plant: *f*, habit (*Forbes 2324-M*); *g*, young flower (*ibid.*); *h*, mature flower (*ibid.*).

in diameter, outer margin plane; seed ovoid with constriction in upper part. Staminate flowers sessile or with pedicels 1–2 mm. long, calyx pilosulose with many, straight, ascending, mostly appressed hairs as well as scattered, shorter, erect, uncinate hairs, lobes with slightly reflexed tip, 3.0–3.5 mm. long, 0.5–1.5 mm. wide; pistil rudiment 0.5 mm. long; filaments 3.0–4.5 mm. long, 0.5 mm. wide; anther sacs 1–2 mm. long, 0.5–0.8 mm. wide.

Type: Gaudichaud, Iles Sandwich. (Type deposited in Museum National d'Histoire Naturelle de Paris [P].)

Range: Islands of Maui, Molokai, and Lanai, dry gulches and lava flows, 2,200 feet altitude.

Specimens examined

Data complete: Molokai.—Kamola, *Faurie 514* (Ho); Slopes of Kolekole, *Forbes 221-Mo* (Ho); Near Laianui, *Degener 4264* (NY, UC). Lanai.—Mts. near Koele, *Forbes 74-L* (Ho); Kaiholena, *Munro 136* (Ho); Kaiholena, *Munro 29* (Ho). Maui.—Nuu, *Forbes 1915-M* (Ho); Auwahi, East Maui, *Rock 8647* (Ho); Olowalu, *Forbes 2324-M* (Ho); Honuaula, *Hillebrand* (K); Slopes of Haleakala, near Kaupo, *Rock 8648* (Ho, GH); Waihualele Gulch, slopes of Haleakala, *Forbes 1824-M* (Ho).

Data incomplete: Maui.—East Maui, *Hillebrand;* Kawaihai i'uke, Hawaii, *Hillebrand* (K); Hawaii, *Remy 196* (in part) (P). Data of last two collections are questionable.

This species was published only as a plate in the volume of drawings of plants collected by Gaudichaud on his second voyage, on "La Bonite." He did not describe the group but the publication of the plate legitimizes the name. As a result of his failure to supply a description, faulty interpretation of the group by subsequent authors has been the rule. It was not until his material was studied that the writer was able to apply the name properly. Hillebrand misapplied the name to what is named here *N. angulata* and Wawra also misunderstood the group, applying the name to *N. kauaiensis.* Although Hillebrand's type is not available, it is likely from the description that his *N. Kahoolawensis* was a Kahoolawe representative of *N. sericea* or, at least, closely related.

The variability in this species is such that a much greater mass of material is necessary before the group can be understood fully. Adequate material may reveal sub-specific entities, for within the material available is some which does have a somewhat different aspect but close examination has failed to reveal any natural bases of segregation. Intensive collecting on Maui, Molokai, and Lanai is necessary before a proper evaluation of the group can be made. The two collections from Lanai have petioles which are half as long as the leaf blades while the leaves of the Maui and Molokai material have petioles one-third or less as long as the leaf blades. In the Maui and Molokai material the main parts of the venation are outlined by very many sub-erect hairs placed almost perpendicularly to the lateral surfaces of these veins. Not all of the Lanai material shows this fringe of hairs. These differences do not seem important enough to justify another group unless subsequent collections show these characters in addition to others of more significance.

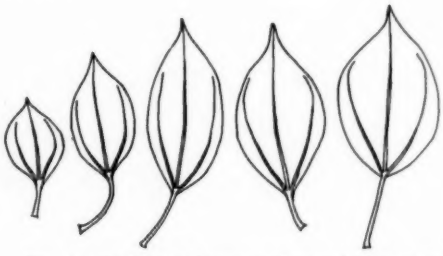

FIG. 19. Outlines of leaves to show variation in leaf shape in *Neraudia sericea* Gaud.

Rock 8647 and part of *Rock 8648* are collections of a staminate plant from Maui and are notable because of the occasional presence of a few teeth on the margin of young leaves. In the Rock collection, used here for Figure 18, the achenes have a constriction which is more obtuse than is typical. In *Forbes 2324-M,*

the pubescence has a tendency to be directed toward the margin in contrast to being more or less erect as is typical. *Forbes 1915-M* has leaves which are smaller than the average of the other collections, averaging 4 cm. long by 2.5 cm. wide. In this collection, also, the nodes are conspicuous because of the mass of pedicels at each node.

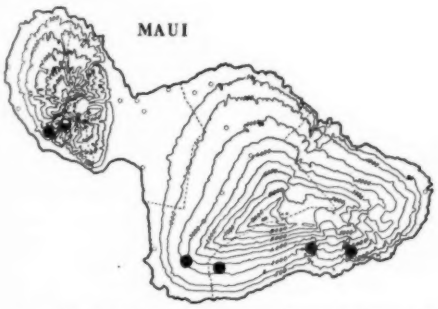

FIG. 20. Distribution of *Neraudia melastomaefolia* Gaud. var. *pallida* Cowan (half-black dots) and *Neraudia sericea* Gaud. on Maui (complete black dots).

Many of the remarks concerning Gaudichaud's plate for *N. melastomaefolia* apply equally well to his plate which stands in lieu of a description of *N. sericea.* The material upon which Gaudichaud based his concept has been carefully examined and the following remarks are based on a comparison of his plate with his material: One of his sheets bears material which is obviously that which was used for the habit sketch, judging from the shape and size of the leaves. The sheet now completely lacks flowers with only scars present to show where flowers were originally situated. The number of scars, however, would indicate far fewer flowers than shown on the plate. The staminate branch shown has the flowers arranged in a most atypical manner and no staminate material collected by Gaudichaud has been received. The beak of the calyx of the pistillate flower is reasonably accurate although that of the fruiting calyx shows this character better. The conspicuous depression at the base of the beak in Gaudichaud's plate is a condition which has not been observed and its existence is doubtful. The achene shown is not completely mature, as the mature forms usually show a deeper, more acute constriction between the apical and basal portion. The architecturally attractive but biologically inaccurate scroll-work shown at the base of the achene does not exist. Likewise, the swollen, evenly rounded lobes of the basal portion are without basis. The staminate flowers and flower parts are unquestionably copied directly from those on the plate of *N. melastomaefolia.* Every single drawing in the two plates of staminate flower parts is identical (except that the style of shading is different, indicating the work of different illustrators), the calyx lobes and stamens have the same angle between them, their posture is the same, and the pubescence is the same in both. The duplication and the fact that no staminate material of this group collected by Gaudichaud has been received suggest that the artist who made this plate had no material of a staminate plant.

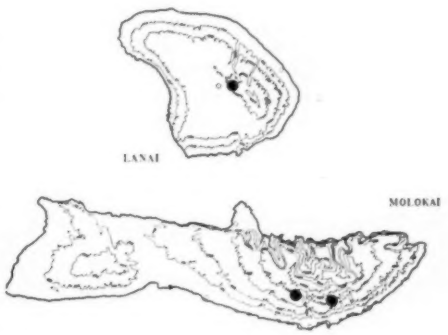

FIG. 21. Distribution of *Neraudia sericea* Gaud. on Molokai and Lanai.

COLLECTORS AND COLLECTIONS OF GENUS

Following is a tabular account of the collections made in the genus *Neraudia* and which are cited in this discussion. Each collection is listed alphabetically and chronologically and the group to which it has been assigned by the writer accompanies each. This table has been prepared to facilitate finding the group to which a particular specimen has been assigned.

COLLECTOR AND NUMBER	GROUP TO WHICH ASSIGNED
BAXTER	
120	*N. melastomaefolia* var. *uncinata*
BERGMAN	
No number	*N. melastomaefolia* var. *uncinata*
CHRISTOPHERSEN	
3682, 3685, 3686	*N. angulata* var. *dentata*
COWAN	
7, 8, 56, 57, 646, 697, 698	*N. melastomaefolia* var. *uncinata*
663, 673, 690, 691, 803, 809	*N. melastomaefolia* var. *parvifolia*
840	*N. angulata* var. *angulata*
836, 837, 839, 849	*N. angulata* var. *dentata*
1054, 1057	*N. melastomaefolia* var. *melastomaefolia*
1055, 1056	*N. melastomaefolia* var. *parvifolia*
COWAN, *et al.*	
477, 478, 479, 480, 481, 482, 483, 484, 485, 486	*N. ovata*
COWAN AND ST. JOHN	
141, 147, 316, 325	*N. melastomaefolia* var. *parvifolia*
333	*N. melastomaefolia* var. *melastomaefolia*
COWAN AND SAKIMURA	
615, 616, 617	*N. melastomaefolia* var. *parvifolia*
COWAN, WEBSTER, AND WILBUR	
750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763	*N. angulata* var. *dentata*
DEGENER	
18190	*N. melastomaefolia* var. *melastomaefolia*
18185	*N. melastomaefolia* var. *uncinata*
18189	*N. melastomaefolia* var. *pubescens*
12803, 12235, 17192, 17506, 17647, 18183, 18189, 18191, 18192	*N. melastomaefolia* var. *parvifolia*
18182	*N. angulata* var. *angulata*
19181	*N. angulata* var. *dentata*
18187	*N. ovata*
4264	*N. sericea*
17117, 18184	*N. melastomaefolia* var. *Gaudichaudii*
DONAGHHO	*N. melastomaefolia* var. *melastomaefolia*
FAGERLUND AND MITCHELL	
842, 1019	*N. ovata*
FAURIE	
514	*N. sericea*
515	*N. melastomaefolia* var. *melastomaefolia*
FORBES	
Nov. 14-21, 1908	*N. melastomaefolia* var. *uncinata*
398-K, 667-K, 829-K, 865-K	*N. melastomaefolia* var. *pubescens*
No number	*N. melastomaefolia* var. *parvifolia*
2365-M, 2470-M	*N. melastomaefolia* var. *pallida*
1828-O	*N. angulata* var. *angulata*
52-K, 1079-K	*N. kauaiensis* var. *kauaiensis*
28-H, 361-H	*N. ovata*
74-L, 221-Mo, 1824-M, 1915-M, 2324-M	*N. sericea*
FOSBERG	
8774	*N. melastomaefolia* var. *uncinata*
9264	*N. angulata* var. *angulata*
FREDERICK	
207, 208, 209, 210	*N. melastomaefolia* var. *melastomaefolia*
206	*N. melastomaefolia* var. *parvifolia*
No number	*N. ovata*
GAUDICHAUD	
208	*N. melastomaefolia* var. *melastomaefolia*
No number	*N. melastomaefolia* var. *melastomaefolia*
No number	*N. ovata*
No number	*N. sericea*
HELLER	
2792	*N. melastomaefolia* var. *pubescens*
2847	*N. kauaiensis* var. *Helleri*
2881	*N. kauaiensis* var. *kauaiensis*
HILLEBRAND	
MACCAUGHEY	
No number	*N. angulata* var. *dentata*
MACDANIELS	
887	*N. melastomaefolia* var. *pubescens*
926	*N. melastomaefolia* var. *parvifolia*
No number	*N. ovata*

COLLECTOR AND NUMBER	GROUP TO WHICH ASSIGNED
MANN AND BRIGHAM	
220	*N. melastomaefolia* var. *melastomaefolia*
624 (part)	*N. melastomaefolia* var. *pubescens*
624 (part)	*N. kauaiensis* var. *kauaiensis*
MEEBOLD	
No number	*N. melastomaefolia* var. *parvifolia*
No number	*N. ovata*
MUNRO	
29, 136	*N. sericea*
NITTA	
37	*N. melastomaefolia* var. *parvifolia*
REMY	
196	*N. sericea*
197	*N. melastomaefolia* var. *melastomaefolia*
198	*N. melastomaefolia* var. *parvifolia*
ROCK	
368, 568, 626, 796, 8838, Dec. 1919	*N. melastomaefolia* var. *uncinata*
2374, 5327, 9007	*N. melastomaefolia* var. *pubescens*
17084	*N. melastomaefolia* var. *parvifolia*
5323, 5922, 17111	*N. kauaiensis* var. *kauaiensis*
4015, 8776	*N. ovata*
8647, 8648	*N. sericea*
RUSS	
No number	*N. melastomaefolia* var. *melastomaefolia*
No number	*N. melastomaefolia* var. *parvifolia*
No number	*N. angulata* var. *dentata*
ST. JOHN	
22269, 22270, 22568	*N. melastomaefolia* var. *melastomaefolia*
12120, 20251	*N. melastomaefolia* var. *uncinata*
22890, 22891	*N. melastomaefolia* var. *pubescens*
9933, 10422, 10599	*N. melastomaefolia* var. *parvifolia*
SEEMAN	
2260	*N. melastomaefolia* var. *melastomaefolia*
SELLING	
3097	*N. melastomaefolia* var. *pubescens*
3203	*N. ovata*
3363, 3669	*N. melastomaefolia* var. *parvifolia*
3697	*N. melastomaefolia* var. *Gaudichaudii*
SKOTTSBERG	
993	*N. melastomaefolia* var. *pubescens*
673, 1956, 1962	*N. ovata*
SUEHIRO	
No number	*N. melastomaefolia* var. *uncinata*
WEBSTER	
1603	*N. melastomaefolia* var. *Gaudichaudii*

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A Preliminary Report on *Parathunnus sibi* in Hawaiian Waters and a Key to the Tunas and Tuna-like Fishes of Hawaii[1]

VERNON E. BROCK[2]

THE BIGEYE TUNA, *Parathunnus sibi* (Temminck & Schlegel), is an important part of the catch of large tunas from Hawaiian waters (Table 1), and yet it is so little known that it seems desirable to publish the preliminary data obtained by the Division of Fish and Game of Hawaii concerning it. These data may be conveniently considered in three categories: (1) field identification of the species principally by external characters, (2) morphometric data, which may be useful in later racial studies as the species is an important one in Japanese as well as Hawaiian landings (Shapiro, 1948: Table 8), and (3) some ecological information based largely on the characteristics of the fishery for the species in Hawaii. Some incidental information on the commercial importance of this species and on the method of taking it is also given.

Parathunnus sibi has been reported from Hawaiian waters by Kishinouye (1923: 444), Jordan and Evermann (1926: 17), and Fowler (1928: 134). Kishinouye's report was hearsay and the descriptions by Jordan and Evermann and by Fowler are hardly sufficient for certain identification. Based on a single sight identification in the San Pedro markets, Kishinouye also reported the occurrence of this species on the west coast of North America. Since then Godsil and Byers (1944: 105–119) have discussed in detail two small specimens from the west coast of Central America. *P. sibi,* originally described from Japanese waters, would seem to span the tropical Pacific in its range.

In the spring of 1948, during a morphometric study of Hawaiian yellowfin tuna, *Neothunnus*

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TABLE 1

LANDINGS OF YELLOWFIN AND BIGEYED TUNA IN THE TERRITORY OF HAWAII, 1947 AND 1948

MONTH	YELLOWFIN		BIGEYED	
	1947	1948	1947	1948
	pounds	*pounds*	*pounds*	*pounds*
January	58,277	87,661	14,496	64,434
February	70,494	92,664	24,079	108,374
March	21,955	88,671	28,472	78,065
April	89,652	72,469	24,176	78,739
May	86,843	60,209	13,661	40,407
June	161,988	123,014	10,086	26,644
July	173,673	130,005	14,858	19,761
August	197,949	132,629	15,646	15,616
September	139,831	96,162	7,077	21,835
October	101,675	71,703	14,455	40,808
November	95,396	102,483	62,393	76,526
December	116,616	100,441	101,269	99,128
Totals	1,314,349	1,158,111	330,668	670,337

macropterus, the identification of the species subsequently determined to be *Parathunnus sibi* proved to be most puzzling until an examination of internal characters was made. It was possible, by inspection, to divide the catch of large tunas auctioned in the Honolulu fish markets into two kinds, both of which, insofar as external characters went, agreed substantially with the available descriptions of *Neothunnus macropterus.* It was suspected that one of the kinds was *Parathunnus* because of its large eye, large head, coarser scalation, and thick, heavy body. However, the available descriptions of *Parathunnus* differed in a number of respects from these fish. Although Kishinouye mentioned that the pectoral fin was relatively shorter in larger fish, Kishinouye as well as Godsil and Byers described *Parathunnus mebachi* Kishinouye, which is here regarded as a synonym of *Parathunnus sibi* (Temmnick & Schlegel), as having a long pectoral fin reaching beyond the anal insertion and to or beyond the anal fin base. The Hawaiian fish examined by me have a pectoral fin which is shorter than that of *Neothunnus* of comparable size and which usually does not reach as far as the insertion of the anal fin. Kishinouye described the anal finlets of *P. sibi* as grayish with a yellow margin; Fowler, who was familiar with Hawaiian material, reported that the finlets were without yellow markings. However, the finlets examined by me have been yellow or orange-yellow with black borders. A 100-pound specimen, the smallest available after several weeks of checking the markets, was purchased for dissection. A study of the internal characters of taxonomic importance—such as the arrangement of the cutaneous circulatory system and the marginal striations on the liver—indicated that the fish was a *Parathunnus,* probably *P. sibi* (Temmnick & Schlegel).

One of the most obvious differences between the Hawaiian specimens of *P. sibi* and the descriptions of this species in literature is, as has been mentioned above, in the relative length of the pectoral fin. Kishinouye's Figure 47 (1923: Pl. 27) shows the tip of the pectoral fin reaching to a vertical line beyond the anal fin base. The photograph of one of the two specimens described by Godsil and Byers (1944: Fig. 59) shows approximately the same relationship. The pectoral fin in the Hawaiian *Parathunnus,* at least in the size range examined by the Division of Fish and Game staff, hardly reaches a vertical line through the insertion of the second dorsal fin, and does not reach the anal insertion at all.

There is an apparent difference in the relative length of the pectoral fins of Hawaiian specimens and of species described in the literature. This is probably attributable to the great differences in size range of fish examined in Hawaii and elsewhere.

However, if the assumption is made that the relationship between the pectoral fin length and total body length is linear when logarithms of the body length are used, then the difference between the Hawaiian material and the available descriptions may be reconciled. Since it seemed to fit his data best, Schaefer (1948) assumed a relationship of this kind between pectoral fin length and body length for *Neothunnus.* Though no proof of the assumption will be offered here for *Parathunnus,* it seems logical to assume that a similar relationship may exist. Where two variables are related linearly when the logarithms of one of them are used, then with an increase in the variables, the variable transformed into logarithmic form will increase much more rapidly on an arithmetical basis than the other. Hence as the fish becomes longer, the pectoral fin becomes relatively shorter, and conversely the smaller fish would have, therefore, relatively much longer pectoral fins. The size range of the Hawaiian *Parathunnus* here reported was 1,191 to 1,900 mm. The specimen figured by Kishinouye (1923), and referred to as immature, was approximately 750 mm. long as estimated by the scale indicated on the plate. The two specimens examined by Godsil and Byers (1944) were 569 mm. and 910 mm. in length, respectively. A line fitted to pectoral fin length and the logarithms of total

length by the method of least squares, when projected for the sizes smaller than those included in the Hawaiian data, indicates that the smaller fish would have, relatively, a much longer pectoral fin. It would seem futile, therefore, to diagnose tunas by such characters as fin lengths without first examining the fins throughout the size range of a species.

Table 2 contains measurements and counts of 20 specimens made in the Honolulu fish markets during the early summer of 1948. The method of measuring and counting described by Godsil and Byers (1944: 125–128) was followed. All measurements were made with large calipers with one fixed and one sliding arm, held parallel. As may be noted in Table 2 characters listed were not determined for all fish. This was because the measurements were made during an auction of the fish, the only practical time and place in which to measure them, and fish would occasionally be purchased and butchered before measurements could be completed. Similarly, it was not possible to determine the sex of all fish since sexes were determined by observation while a dealer butchered his recently acquired merchandise.

The computations for the regression lines for the various characters given in Table 2 have not been given here, since such comparisons of regression lines can be made with comparable data obtained for other localities and by statistical methods that seem appropriate. It does not seem worthwhile to suggest the design of a statistical scheme of analysis here by computing part of it, especially since most workers would prefer to take the field data as given in Table 2 as their starting point.

Table 1 and Figure 1 show that the largest landings of *Parathunnus* are made during the winter months. Many of the fishermen alter their gear during this period to increase the catch of this species. The Hawaiian catch of *Parathunnus* is taken on flagline or longline gear. This is an unanchored set line with hooks at approximately 30-fathom intervals and floated by buoys in deep water. The hooks are attached to leaders up to 20 fathoms long in fishing for *Neothunnus* during the summer months. In fishing for *Parathunnus,* and *Neothunnus* too, during the winter months these leaders are often lengthened several fathoms. For a detailed description of longline gear see Shapiro (1948: 40–44). *Parathunnus,* aside from the occasional capture of small individuals, is rarely taken by surface fishing techniques such as trolling or fishing with live bait.

This information would imply that *Parathunnus* is not a surface fish but that, at least during daylight, it feeds in the layers below 20 fathoms. The large eye characteristic of the species would lend weight to such an assumption. Kishinouye's discussion (1923: 444–445) of the habits of the species likewise indicates that it is not a surface fish but may approach nearer the surface at night.

Parathunnus, as taken in the Hawaiian flagline fishery, is a large tuna. Examples under 80 pounds are rare; the average weight of the specimens landed during January to September, 1948, for example, was 157.8 pounds. The maximum weight of this species landed in Hawaiian waters approaches or exceeds 300 pounds. Kishinouye, however, gives a maximum weight of 86 kilograms (190 pounds) for Japanese examples, but as he states that a fish of this weight would be about 2 meters long, it is probable that his estimate of the maximum weight is in error. A 2-meter long specimen with the body proportions of the Hawaiian fish would weigh about 334 pounds.

The fact that *Parathunnus* is rarely taken by surface fishing methods has some interesting connotations. The present fishing grounds for the species in the Pacific are those grounds on which flagline fishing gear is employed. Although in Hawaii *Parathunnus* is from one-half to two-thirds as important as *Neothunnus* in the landings of large tunas, in Japanese landings (Shapiro, 1948, table 8) in some years, it was far more important than *Neothunnus.* Aside from the two specimens discussed by Godsil and Byers (1944: 105–119) and one

TABLE 2

MORPHOMETERIC DATA (LISTED IN ASCENDING ORDER BY LENGTH) FOR 20 HAWAIIAN PARATHUNNUS*

Total length	1,191	1,236	1,279	1,290	1,342	1,372	1,373	1,422	1,470	1,475	1,495	1,542	1,570	1,592	1,593	1,670	1,697	1,760	1,783	1,900
Date†	4/14	4/14	6/2	4/16	6/2	4/16	4/16	6/2	4/12	4/13	6/2	5/25	5/6	5/25	3/24	4/12	5/13	5/17	4/14	6/4
Weight	83	90	98	101	115	137	128	125	163	151	145	164	180	181	189	214	201	248	261	275
Head length	354	369	372	382	404	404	409	410	447	429	447	450	457	461	467	480	469	497	516	533
From snout tip to 2nd dorsal insert	649	679	686	712	734	743	763	748	823	811	825	819	847	862	858	884	878	916	940	989
From snout tip to anal insert	730	759	774	779	834	837	844	862	929	901	905	919	940	998	970	.....	1,024	1,026	1,083	1,114
From snout tip to pectoral insert	359	365	380	385	397	400	406	419	450	420	446	446	448	457	471	472	468	487	514	526
Greatest body depth	331	339	356	353	352	391	509	369	412	425	382	419	417	411	425	.....	435	487	480	480
Place of greatest body depth	7-D	7-D	8-D	7-D	6-D	9-D	9-D	7-D	7-D	6-D	7-D	7-D	7-D	8-D	.....	.....	4-D	6-D	8-D	7-D
Length base 1st dorsal	315	331	321	329	346	359	349	336	397	377	382	383	395	412	377	.....	398	428	450	500
Anal fin length	161	200	195	187	188	196	176	223	232	214	209	225	242	243	260	252	252	274	266	268
2nd dorsal fin length	149	192	200	195	205	193	183	215	257	231	214	233	253	238	.....	245	254	278	264	263
Spread of caudal	431	465	467	432	480	469	460	495	.....	525	522	598	579	566	635	.....	642	688	719	707
Pectoral fin length	330	401	374	357	368	357	341	383	366	366	371	377	386	373	382	380	370	396	413	351
Gill raker count	9/19	7/18	9/19	9/18	9/19	8/19	8/19	9/18	.....	6/20	9/20	9/19	8/18	7/20	9/18	.....	9/18	7/17	8/18	8/18
Sex	♀	♂	.....	♀	.....	.....	.....	.....	♂	.....	.....	♀	.....	.....	♀	♀	♂	.....	♂	.....

* Weights are in pounds and lengths are in millimeters. Place of greatest body depth (7-D, 8-D, etc.) refers to the seventh or eighth dorsal spine. In the gill raker count (9/19, 7/18, etc.) the first number refers to the number of gill rakers on the upper limb of the gill arch, the second number to the number of gill rakers on the lower limb.

† Measurements made on dates indicated in March, April, May, and June, 1948.

mentioned by Kishinouye (1923: 444), *Parathunnus* is not known from the eastern tropical Pacific, yet it may well be abundant in the tuna grounds now exploited by the California tuna fishermen. Its abundance in the eastern Pacific will not be determined until fishing gear capable of taking it is tried in those waters.

The *Parathunnus* fishery serves to point up the fact that the fishing techniques now available for taking oceanic species may be inadequate to exploit these species in proportion to their actual abundance in the sea. There is a possibility that in some areas now fished, marine food resources of considerable magnitude, not only untapped but unknown, may exist.

KEY TO THE TUNAS AND TUNA-LIKE FISHES OF HAWAII

The following key is to the tunas and tuna-like fishes reported from Hawaiian waters. Those species marked with an asterisk are commonly taken about the Hawaiian Islands; those not so marked either do not occur in this area, or else are rare, and have not been seen by the author among fish landed at any Hawaiian port.

Two species, *Sematbunnus itosibi* (Jordan and Evermann) and *Grammatorcynus thompsoni* (Fowler), described from the Hawaiian Islands are not included in the key. *Sematbunnus itosibi* = *Neothunnus macropterus*, as understood here; *Grammatorcynus thompsoni* is probably a scomberomorid or gempylid synonymous with *Lepidocybium flavo-brunneum* (Smith).

1. First dorsal fin with 10 to 18 spines; body not over five times as long as greatest depth 2
   First dorsal fin with about 25 spines; body long and slender, at least six and a half times as long as greatest depth. Ono ....**Acanthocybium solandri* (Cuvier & Valenciennes)
2 (1). Body completely scaled, scales may be enlarged in corselet and on lateral line 5
   Body naked, without scales, except for the scaly corselet and lateral line 3
3 (2). The last spine in the first (spinous) and the first ray in the second (soft rayed) dorsal fins close to-

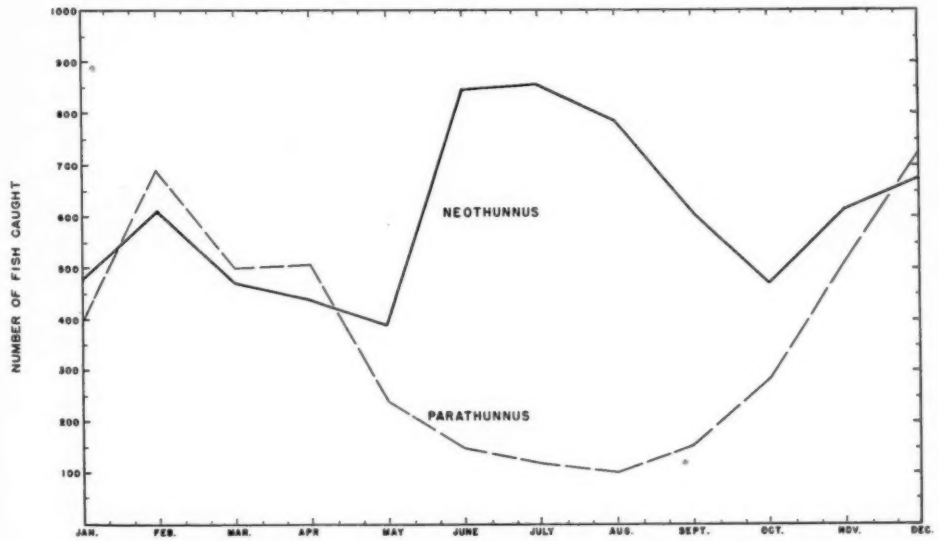

FIG. 1. Number of tuna caught by flagline in Hawaiian waters during 1948.

gether, separated by a distance equal to about one-fifth of head length 4

The first and second dorsal fins far apart, separated by a distance equal to about one-half the head length or more. Frigate mackerel .....**Auxis thazard* (Lacepede)

4 (3). Four dark longitudinal stripes present on lower surface below lateral line of side and on belly. Aku .. ....**Katsuwonus pelamis* (Linné)

No dark longitudinal stripes below lateral line, about 12 dark wavy streaks on back. Kawakawa.... ...**Euthynnus yaito* (Kishinouye)

5 (2). Dorsal finlets with some yellow, usually largely yellow 7

Dorsal finlets without any yellow markings 6

6 (5). Spines in first dorsal fin 14 or fewer in number. Bluefin tuna ....*Thunnus thynnus* (Linné)

Spines in first dorsal fin 18 in number. Bonito .....*Sarda chilensis* (Cuvier & Valenciennes)

7 (5). Gill rakers on upper and lower branch of first gill arch fewer than 32 in number, usually fewer than 30 8

Gill rakers on upper and lower branch of first gill arch 36 to 39 in number; pectoral fin does not reach to a vertical through second dorsal fin insertion; anal finlets silvery. Black tuna, Maguro .... *Thunnus orientalis* (Temmnick & Schlegel)

8 (7). Gill rakers on upper and lower branch of first gill arch 24 or more in number; air bladder present; pectoral fin reaches, in most of the species included here, to or beyond a vertical through the last spine of the first dorsal fin 9

Gill rakers on upper and lower branch of first gill arch 23 or fewer in number; no air bladder; pectoral fin does not reach to a vertical through caudal end of first dorsal fin; size small, usually less than 25 pounds ....*Kishinoella rara* (Kishinouye)

9 (8). Anal finlets with yellow or orange color; a vertical line through tip of pectoral fin usually falls anterior to end of anal fin base, at least in larger specimens of over 70 or 80 pounds 10

Anal finlets dusky without yellow or orange color; a vertical line through tip of pectoral fin usually falls posterior to end of anal fin base; size medium to small, rarely more than 70 or 80 pounds, usually much less. Albacore ....**Germo alalunga* (Gmelin)

10 (9). Dorsal and anal finlets a clear yellow, very narrowly black edged; some large individuals of this species may have elongate second dorsal and anal fins, reaching nearly to the caudal fin or beyond; number of gill rakers on upper and lower limb of first gill arch usually 30 (27 to 31); liver without marginal striations. Yellowfin tuna, Ahi ....**Neothunnus macropterus* (Temmnick & Schlegel)

Dorsal and anal finlets with a broad black border, anal finlets often with an orange rather than yellow color; second dorsal and anal fins never greatly elongated, a little longer than the longest spines of the first dorsal fin and much shorter than pectoral fin; number of gill rakers on upper and lower limb of first gill arch usually 27 (24–29); liver with marginal striations. Bigeye tuna .....**Parathunnus sibi* (Temmnick & Schlegel)

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NOTES

Arthropods of Potential Medical and Veterinary Importance from Ponape, Caroline Islands

The list presented here is based on a collection made by the writer on the island of Ponape during January and February, 1948.

Mites

Trouessartia rosterii Berlese; host—starling (*Aplonis opaca ponapensis*). *Myocoptes musculinus* (Koch); host—mouse. *Radfordia affinis* (Poppe); host—mouse. *Echinolaelaps echidninus* (Berlese); host—rat. *Laelaps nuttalli* Hirst; host—rat.

Ticks

Boophilus sp., probably *B. annulatus australis* (Fuller) previously reported by Alicata (1948, *Pacific Sci.*); host—dairy cow. *Amblyomma* sp.; host—domestic pig.

Sucking lice

Pediculus humanus var. *capitus* Degeer. *Haematopinus adventicius* Newm.; host—domestic pig.

Biting lice

Lipeurus caponis (L.), *Menopon gallinae* (L.), and *Oxylipeurus angularis* Peters; host—wild chicken (*Gallus gallus*). *Actornithophilus epiphanes* (K. & Ch.); host—tern (*Anous stolidus pileatus*). *Myrsidea* sp.; host—starling (*Aplonis opaca ponapensis*).

Biting midge

Culicoides esakii Tokunaga. Annoying in the forests of the interior.

Mosquitoes

Aedes aegypti (L.); *Aedes* sp.; *Aedes* sp.; *Culex quinquefasciatus* Say; *Culex annulirostris* Skuse; *Culex* sp. (See paper by Knight and Hurlbut in *Jour. Washington Acad. Sci.*, 1949, in press.)

Filth-frequenting flies

Chrysomya megacephala (F.); *Chrysomya rufifacies* (Macq.); *Chrysomya* (*Microcalliphora*) *nigripes* Aub.; *Hemipyrellia tagaliana* (Big.); *Musca domestica* L.; *Musca sorbens* Wd.; *Ophyra nigra* (Wd.); *Ophyra chalcogaster* (Wd.); *Sarcophaga peregrina* (R.D.); *Sarcophaga knabi* Pk.

Biting flies

Stomoxys calcitrans (L.); *Siphona irritans* (L.).

Parasitic flies

Ornithoctona plicata (Olfers); host—pigeon (*Ducula oceanica townsendi*). *Ornithoica pusilla* (Schin.); hosts—wild chicken (*Gallus gallus*) and starling (*Aplonis opaca ponapensis*). *Cyclopodia* sp.; host—fruit bat.

Fleas

Ctenocephalides canis (Bouche); hosts—dog, pig, goat.

I wish to acknowledge, with thanks, the assistance of individuals who made identifications of the above material: mites, E. W. Baker; fleas and lice, C. F. W. Muesebeck; parasitic flies and biting midge, Alan Stone; filth-frequenting flies, C. W. Sabrosky; birds, Herbert Friedman. Also I wish to express my appreciation for the assistance given by John I. Thomas, Chief Hospitalman, U. S. Navy, in collecting the material and preparing the vertebrate specimens.—*Herbert S. Hurlbut, Commander, MSC, USN, Naval Medical Research Institute, Bethesda, Maryland.*

News Notes

Building of the new laboratory of the Pacific Oceanic Fishery Investigations is expected to begin in July, 1949. The laboratory, which is to be the headquarters of POFI, will be erected on the campus of the University of Hawaii. A temporary headquarters office is now located in Room 811, Appraisers Building, 630 Sansome Street, San Francisco 11, California. First appointments to the staff of POFI include: Oscar E. Sette, Director; Fred F. Johnson, Assistant Director; Milner B. Schaefer, Chief, Section of Biology and Oceanography; Carl B. Carlson, Chief, Section of Exploratory Fishing; and Charles Butler, Chief, Section of Technology.

Elwood C. Zimmerman, Associate Entomologist of the Experiment Station, Hawaiian Sugar Planters' Association, and Curator of Entomology, Bernice P. Bishop Museum, has received a special appropriation from the Hawaiian Sugar Planters' Association to aid him in completing additional volumes of his *Insects of Hawaii,* a project of the Experiment Station's Department of Entomology. Mr. Zimmerman is now at the British Museum of Natural History studying the types of Hawaiian insects deposited there in collections made by early visitors to Hawaii.

The following publications of the Natural Resources Section, General Headquarters, Supreme Commander for the Allied Powers, have been received. Each report includes a list of all those published, their distribution, and rules for obtaining them.

Wildlife Conservation in Japan. Report No. 116. 24 pp., 7 figs.

Aquatic Resources of the Ryukyu Area. Report No. 117. 54 pp., 14 figs., 13 tables.

Waterfowl of Japan. Report No. 118. 106 pp., 38 figs., 1 table.

[*Important Trees of Japan.* Report No. 119. Not received.]

Coal Fields of Eastern Honshu, Japan. Report No. 120. 34 pp., 8 figs., 1 pl., 3 tables.

An announcement has been received telling of the change in name of the journal *Terrestrial Magnetism and Atmospheric Research.* Beginning with Volume 54, No. 1, March, 1949, this international quarterly will be known as the *Journal of Geophysical Research,* and will "endeavor to cover a broad range of subjects on geophysical research directed toward scientific goals, as distinguished from applied or industrial geophysics." The journal will be edited by Merle A. Tuve, with the assistance of Walter E. Scott, and the advice and experienced help of J. A. Fleming, who has been associated with the publication of *Terrestrial Magnetism and Atmospheric Research* almost since its inception in 1896 and who was its able editor from 1928 to 1948. The Editorial Office of the journal is at 5241 Broad Branch Road, N. W., Washington 15, D. C. The journal is published by the Johns Hopkins Press, Baltimore 18, Maryland, and subscriptions (at $3.50 a year) should be directed to that address.

The Hawaiian Botanical Society commemorated its twenty-fifth anniversary on May 2, 1949, with a program titled "Hawaiian Botany Twenty-Five Years Ago" and by election of the following charter members to the first honorary life memberships in the Society: Elizabeth D. W. Brown, F. B. H. Brown, E. L. Caum, F. G. Krauss, Maude F. Lyon, Harold L. Lyon, G. A. McEldowney, Elizabeth B. MacNeil, Willis T. Pope, and O. H. Swezey.

Among papers to be included in forthcoming issues of *Pacific Science* are:

Notes on New Zealand Marine Algae I—Victor W. Lindauer.

A Catalogue of the Heterocerous Lepidoptera of French Oceania—P. E. L. Viette.

Ocean Temperatures of the Hawaiian Island Area—Dale F. Leipper.

The Status of Steller's Albatross—O. L. Austin.

Three papers on luminescence in marine fishes—Yata Haneda.

A Treatise on Marine Ecology and Paleoecology.—This is the eighth of a series of publications designed to aid in the preparation of a treatise on marine ecology and paleoecology. Like the previous volumes, it includes notes on current activities, bibliographies, papers, and abstracts of pertinent papers as well as some of the completed units of the proposed treatise.

LADD, HARRY S., *et al.* Report of the Committee on a Treatise on Marine Ecology and Paleoecology, 1947–1948. No. 8, December, 1948. Division of Geology and Geography, National Research Council, 2101 Constitution Ave., Washington 25, D. C. 117 pp. $1.00.

The former editor-in-chief of *Pacific Science*, A. Grove Day, has collaborated with Carl Stroven, University of Hawaii Librarian, in the preparation of a delightful anthology of the literature of the Pacific. It has just been released by the publisher, Macmillan Company, under the title, *The Spell of the Pacific: An Anthology of Its Literature.* It runs the gamut from Captain Bligh and Charles Darwin to James Norman Hall and Charles Nordhoff. All interested in the Pacific in any way will find much of interest in the 940 pages of this volume.

STROVEN, CARL, AND A. GROVE DAY. The Spell of the Pacific: An Anthology of Its Literature. xx + 940 pp. The Macmillan Company, New York, 1949. $6.50.